# Evaluation of Simple Mesoscale Models for Use in TESS



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## ABSTRACT

Three mesoscale models are evaluated for use in the Tactical Environmental Support System (TESS): single level primitive equation models (the Lavoie and Eddington models), and a one-level sigma coordinate model that uses the primitive equations without mass continuity (the Mass-Dempsey model). The Mass-Dempsey model performed adequately when applied to the Monterey Bay region of California while the Lavoie model did not. Coding errors in the Eddington model prevented an accurate evaluation in this study. The current formulation of the Lavoie model requires less computer time and is easier to initialize than the Mass-Dempsey model. Results show that the Mass-Dempsey model performs well while the Lavoie model does not. Future work on the Mass-Dempsey model should include an effort to improve the initialization so that the geopotential height and temperature gradients represent those of the area of interest.

ACKNOWLEDGEMENTS

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## 1. Introduction

Prediction of wind flow in a complex coastal environment is a challenging task that continues to be of interest to the U.S. Navy, specifically for use in the Tactical Environmental Support System (TESS). TESS is a computer workstation which provides environmental information for the Navy's tactical decision makers and is discussed in detail in Phegley and Crosiar (1991).

According to Mass and Dempsey (1986), global and regional models have improved to the point where they adequately predict larger scale synoptic conditions; however, conversion of these forecasts into local and mesoscale weather is still a problem. One solution is to increase the resolution of a global or regional model to that desired for mesoscale prediction. The problem with this is that computational requirements for the model would far exceed the capability of TESS.

Another solution is to run simple mesoscale models which use observations or output from the more complex models for initialization. Until recently, computational requirements of simple mesoscale models were beyond the capabilities of TESS. However, the TESS hardware has been upgraded to a system which is now capable of running simple mesoscale models. Hence, it has become increasingly important for the Navy to develop and evaluate these models for use in TESS.

Of the simple diagnostic models, Mass and Dempsey (1986) cite three types: mass conservation models, one level primitive equation models, and one level sigma coordinate models that use the primitive equations without the continuity equation. Mass (1984) evaluated one of each type of model and found that a one-level sigma coordinate model, hereafter called the Mass-Dempsey model, consistently outperformed the others in the three areas studied (Western Washington, San Francisco Bay Area, and Subic Bay in the Philippines). The one level primitive equation model demonstrated wind flow problems near the domain boundaries and did not perform as well as the Mass-Dempsey model in a qualitative sense. Results also indicate that this mass conservation model rarely simulated realistic flow patterns.

On the other hand, Eddington (1988) obtained reasonable results with a one level primitive equation model with a well-mixed boundary layer for Point Mugu, California. This model, hereafter referred to as the Eddington model, correctly simulates high winds through the Santa Barbara channel, low winds in the lee of the Channel Islands, and deflection of air flow around terrain.

This study evaluates three models: the Mass-Dempsey model, Eddington model and an implementation of the original one level primitive equation model with a well-mixed boundary layer (La-

voie, 1972), hereafter referred to as the Lavoie model. No representative from the mass conservation model type is included in this study, partly because of the poor performance shown for this type of model in Mass (1984). In the evaluation, emphasis is placed on a model's ability to diagnose wind flow in the Monterey Bay Area. The evaluation also places emphasis on considerations important for operations. These include model run-time, complexity of initialization data, and ease of model operation.

As part of this evaluation, the three models were developed to run on an HP-9000/835 computer (96 Megabytes of memory, 14 Million Instructions/Second). This computer is reportedly about three times faster than TESS (3) which has three processors, each one contributing 4 Million Instructions/Second (Tsui, personal communication). Interactive graphics were added to each model at prescribed timesteps with laser printed hardcopy capability. The Naval Environmental Operational Nowcasting System (Tsui, 1991) global 5 km global terrain database and 10 km global land-sea data base were implemented so that, with little effort, the models could be run in any area of the world. Appendices I, II and III describe specifics for model use and program modification for each of the Lavoie, Eddington and Mass-Dempsey models respectively.

## 2. Model Descriptions

Comprehensive description of the three numerical models evaluated in this study is found in Lavoie (1972), Eddington (1988), and Mass and Dempsey (1985). This section addresses some of the important differences between the models, methods of initialization, and changes made to the models for the current study.

### 2.1 Model Initialization

Model initialization considerations are critical to an evaluation of these models. While researchers have virtually unlimited time in which to develop an initialization data set, operational forecasters function with fewer resources and severe time constraints. Therefore, model initialization used in this evaluation is presented in detail. The Lavoie and Eddington models are similar in their initialization and are discussed together. The Mass-Dempsey model differs from the other two models significantly.

#### 2.1.1 Lavoie and Eddington Model Initialization

Initialization data required for the Lavoie and Eddington models are similar and are discussed in Appendices I and II. Vertical parameters were derived from the nearest upwind sounding (e.g., Oakland or Vandenberg AFB). Surface parameters were taken from the offshore buoys.

Figure 1 shows the basic assumption made for these two models. The diagnostic layer of the model is the well-mixed (constant $\Theta$) layer, capped by a zero-order discontinuity inversion. The depth of the super-adiabatic layer ($z_s$) is always assumed to be 50 m. The height (h) and temperature ($\bar{\Theta}$) of the mixed layer are taken to be the height and temperature of the base of the inversion. The temperature at the top of the inversion ($\Theta_h$) is also prescribed. For the Lavoie model, the lapse rate above the inversion is required and was computed using the next two standard levels. In most cases, this will be the 850 mb and 700 mb levels. For the Eddington model, a single "free atmosphere" temperature is needed. The 700 mb temperature was used for these simulations.

The initial wind field is prescribed using a single wind direction and speed which is then used at all of the grid points. Typically the Monterey Bay buoy (46042) and San Francisco buoy (46026) were used for this initialization. Land and sea temperatures were given representative values of 23°C (73°F) and 11°C (52°F) respectively for all simulations.

2.1.2 Mass-Dempsey Model Initialization

Initialization data required for the Mass-Dempsey model are discussed in Appendix III. Many of the parameters required to run this model are similar to those required by the Lavoie and Eddington models. Lapse rates are computed from aircraft data collected at Salinas airport.

Unlike the Lavoie and Eddington models, the Mass-Dempsey model requires heights and temperatures at a reference pressure level which can be determined either from radiosonde observations or NMC analyses (Mass and Dempsey, 1985). In this paper, the data are interpolated objectively from the Navy Operatioal Global Atmospheric Prediction System (NOGAPS) 850 mb analysis (Barker, et al., 1989). Although Mass and Dempsey (1985) used 16 evenly spaced data points, this study found that a 4 point initialization (points from each corner of the domain) resulted in less work, fewer errors, and faster convergence than the 16 point initialization.

In general, results for the 4 point initialization converge quicker and results are not substantially different than for the 16 point initialization. One exception is when a synoptic feature (e.g., a trough) lies within the domain of the model. The 4 point initialization does not adequately represent the feature and hence results in an erroneous forecast. A 16 point initialization resolves the feature, but the model frequently fails to converge. In the event that the model does not converge, P. Speers-Hayes (personal communication) suggests that the model be initialized with constant gradients of temperature and height taken from the area of interest and applied to the whole domain. An example of how to apply this method is shown in the next section.

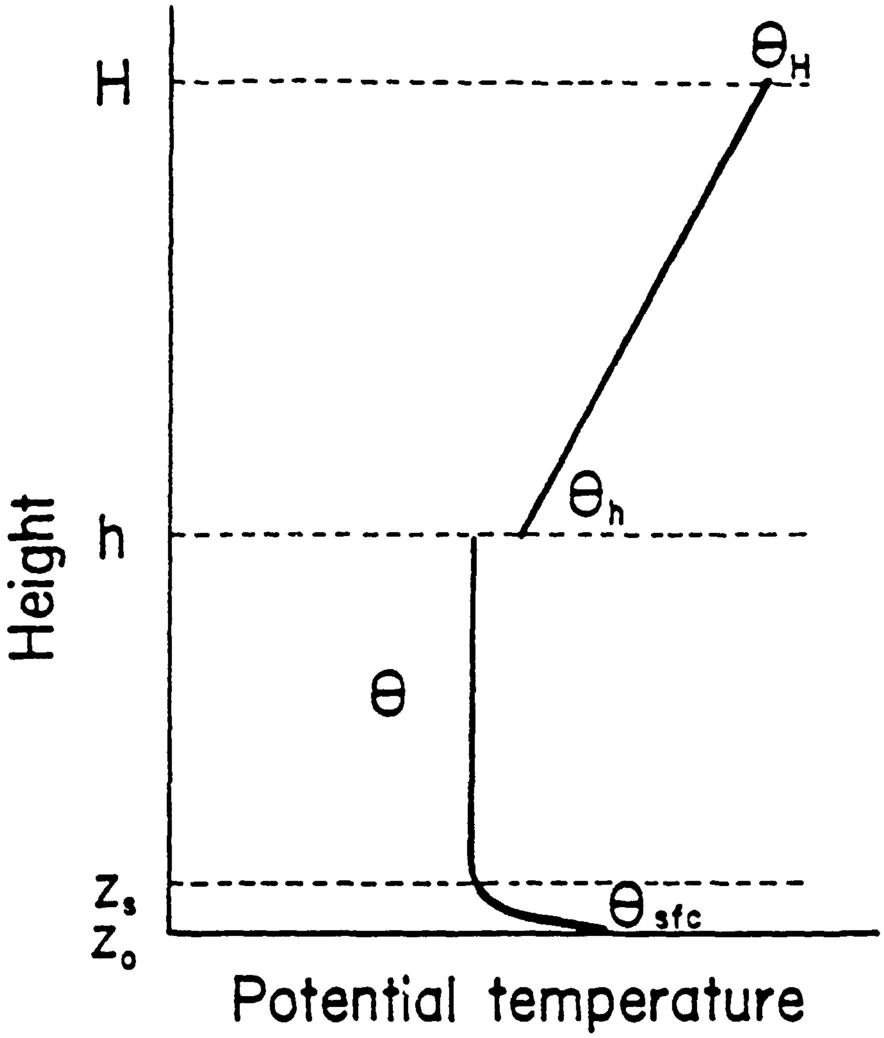



Fig. 1 Assumed vertical temperature structure for Lavoie and Eddington models.

## 2.2 Model Changes

For the current study, some changes were made to the three models. These included:

* The inclusion of an interactive graphics package in all three models using NCAR graphics. The user can select what fields to display and overlay, with the option to print them on a laser printer.

* Use of a global terrain (5' resolution) and land-sea (10' resolution) data base.

* Protruding terrain in the Lavoie model. This formulation was used in the Eddington model (see Eddington, 1988 for a description).

* Convergence test in the Lavoie and Eddington models. The methodology used is the same as that described in Mass and Dempsey (1985) where the domain averaged change in the wind field falls below a specified level ($1.0 \times 10^{-5}$ for the current study).

## 3. Model Simulations

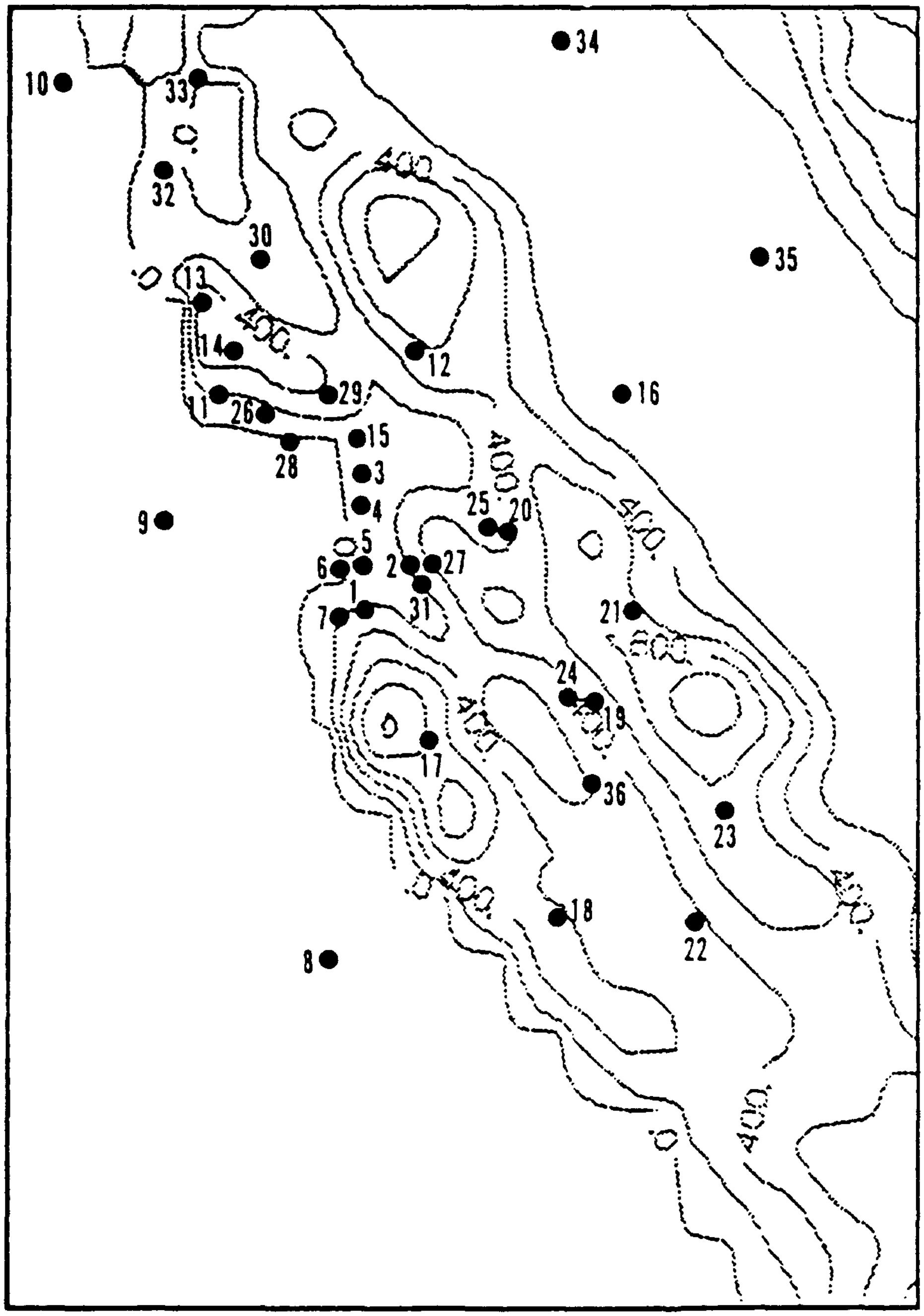
The following section describes model simulations for the dates during summer, 1991 for the Monterey Bay Area. The domain for all model runs was 3 Degree Latitude square centered off the Monterey Peninsula (Fig. 2). The extensive network of observations was provided by the many organizations listed in Fig. 2 and in the Acknowledgements section of this report. The Lavoie and Eddington models are coded so that the domain is 75 by 75 grid points and the resolution is 5 km. The Mass-Dempsey model is restricted to 52 by 52 grid points which define a resolution of approximately 7.5 km for the Monterey Bay Area domain.

With the resolutions specified above, runtimes for each model were obtained. These runtimes measure the computer time used by the models, which is independent of the activity of other users on the system. The Lavoie model runs in the least amount of time (approximately 300 seconds for a 30 hour simulation), followed by the Mass-Dempsey model (approximately 500 seconds for a 15 hour simulation), and the Eddington model (approximately 2500 seconds for a 30 hour simulation).

Unfortunately due to time constraints of this project, the authors were unable to completely debug the code of the Eddington model. Thus, the results obtained will not be discussed. From some of the Eddington simulations, the authors feel that this model holds great promise and that work should continue on it.

### 3.1 June 28: Trough Offshore, Overcast, Southwesterly Flow

On June 28, 1991, a weak mid-latitude trough was approaching




1. Monterey Airport
2. Salinas Airport
3. Watsonville Airport
4. Moss Landing
5. Fritzsche Field (Fort Ord AAF)
6. Marina Beach
7. Point Pinos
8. Buoy 46028
9. Buoy 46042
10. Buoy 46026
11. Waddel Beach
12. Morgan Hill CDF
13. Eagle Rock CDF
14. Mt. Bielawski CDF
15. Corralitos CDF
16. San Luis Reservoir
17. Chews Ridge CDF
18. Three Peaks CDF
19. Chalone Peak CDF
20. Hollister CDF
21. Call Mountain CDF
22. Bradley CDF
23. Smith Mountain CDF
24. Pinnacles
25. Hollister APCD
26. Davenport APCD
27. Salinas APCD
28. Santa Cruz Yacht Harbor
29. Mt. Umunhum
30. Moffett NAS
31. Salinas WR
32. San Francisco Intnl. Airport
33. Alameda NAS
34. Stockton
35. Merced
36. King City APCD

Fig. 2 Station location map for Monterey Bay Area.

the California coast and brought mid- and low-level stratiform clouds to the Monterey Bay area. The 0000 GMT (1700 PDT) 850 mb chart (Fig. 3) shows that the trough is reflected in lower geopotential heights and lower temperatures off the California coast. Wind observations for approximately 2100 GMT (1400 PDT) show southerly to southwesterly winds along the central California coast (Fig. 4).

The upwind sounding from Vandenberg AFB at 1200 GMT (Fig. 5) shows a warm, moist, deep boundary layer associated with the southwesterly flow. A capping inversion of moderate intensity ($\Delta\Theta$ = 4.6°C) is located at 755 mb (2500 m).

### 3.1.1 Lavoie Model

The model converges to a solution rather quickly. This is not surprising since the inversion height is well above all of the topography (highest terrain ≈ 1500 m). Thus there is little adjustment to the initial wind field due to the topography. This is shown by the resulting wind field (Fig. 6). Aside from a slight reduction in speed in the lee of Mt. Hamilton, the wind field is virtually unchanged from its initial state. Comparing this with the observed winds in figure 4 it is obvious that this simulation is totally unrealistic. Thus it appears that intializing the model with a deep boundary layer (i.e. 2500 m) will not produce realistic results.

The predicted height of the mixed layer (Fig. 7) does show that the model correctly "feels" the topography. Relative height minima (maxima) downwind (upwind) of the mountain peaks due to sinking (rising) motion appears realistic.

As a test, the model was re-run with a boundary layer depth of only 300 m. The results (Fig. 8) were much more realistic, with turning of the winds on the Monterey Pennisula and channeling in the Salinas Valley. The model failed to create the northwesterlies observed at Salinas and was too weak on the wind speed in general. It is suspected that the northwesterlies at Salinas are due to a sea breeze effect since prior to 1400L, winds at Salinas were southerly.

### 3.1.2 Mass-Dempsey Model

The first run is for a 4 point initialization in which data are extracted for each of the four corners of the domain. The resulting flow pattern (Fig. 9) shows regions of westerly and northerly winds while surface wind observations show that the flow should be south or southwesterly (Fig. 4). The reason for this is that the trough is within the model domain and therefore between initialization grid points.

In a second run, the model is initialized with a constant gradient computed from a small area off the coast where the winds are representative of the observed wind flow. In this case, the

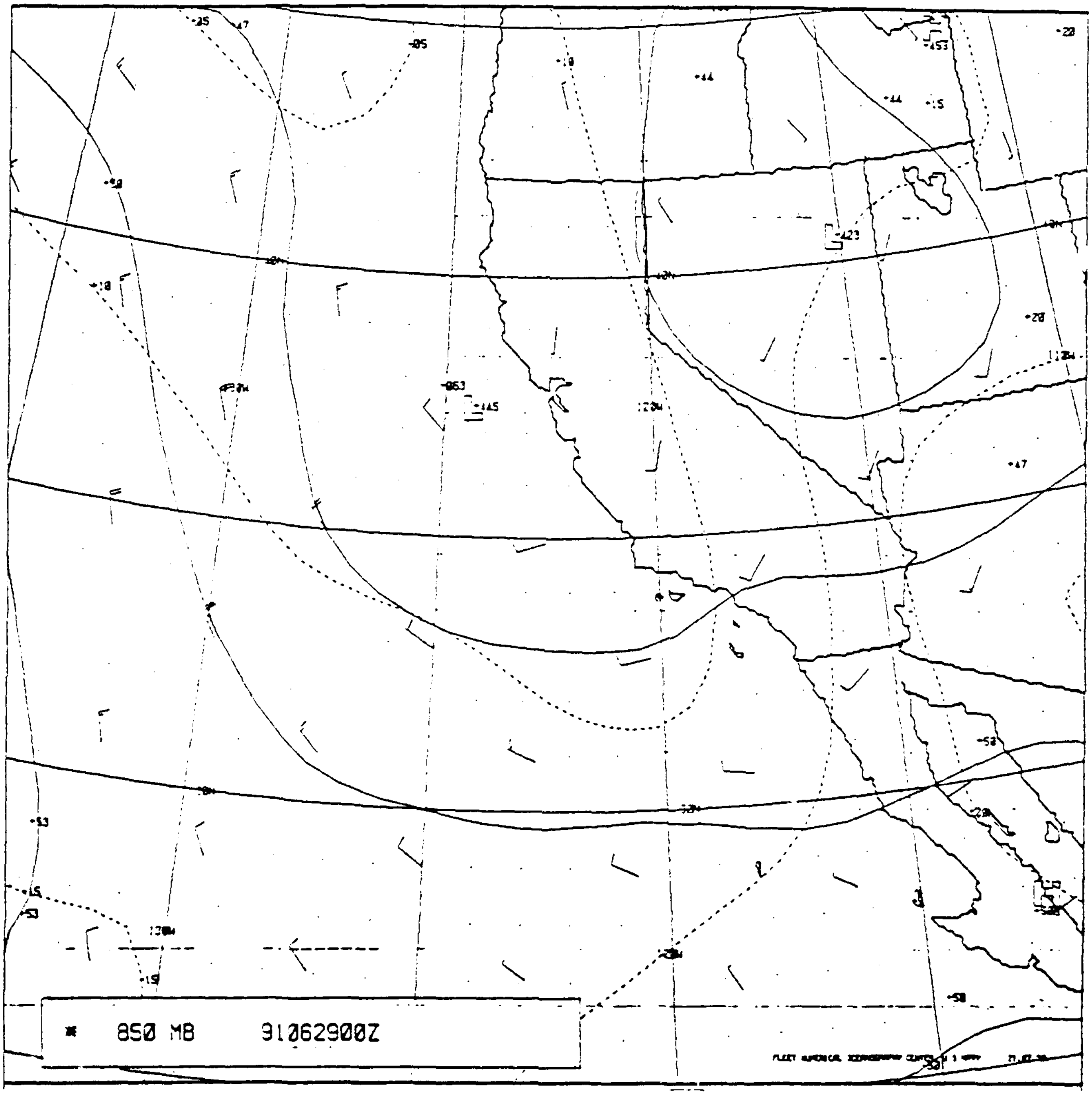



Fig. 3 850 mb analysis at 0000 GMT 29 June 1991 (1700 PDT 28 June).

Fig. 4    Surface wind observations at 2100 GMT 28 June 1991 (1400 PDT). Terrain height is in meters.

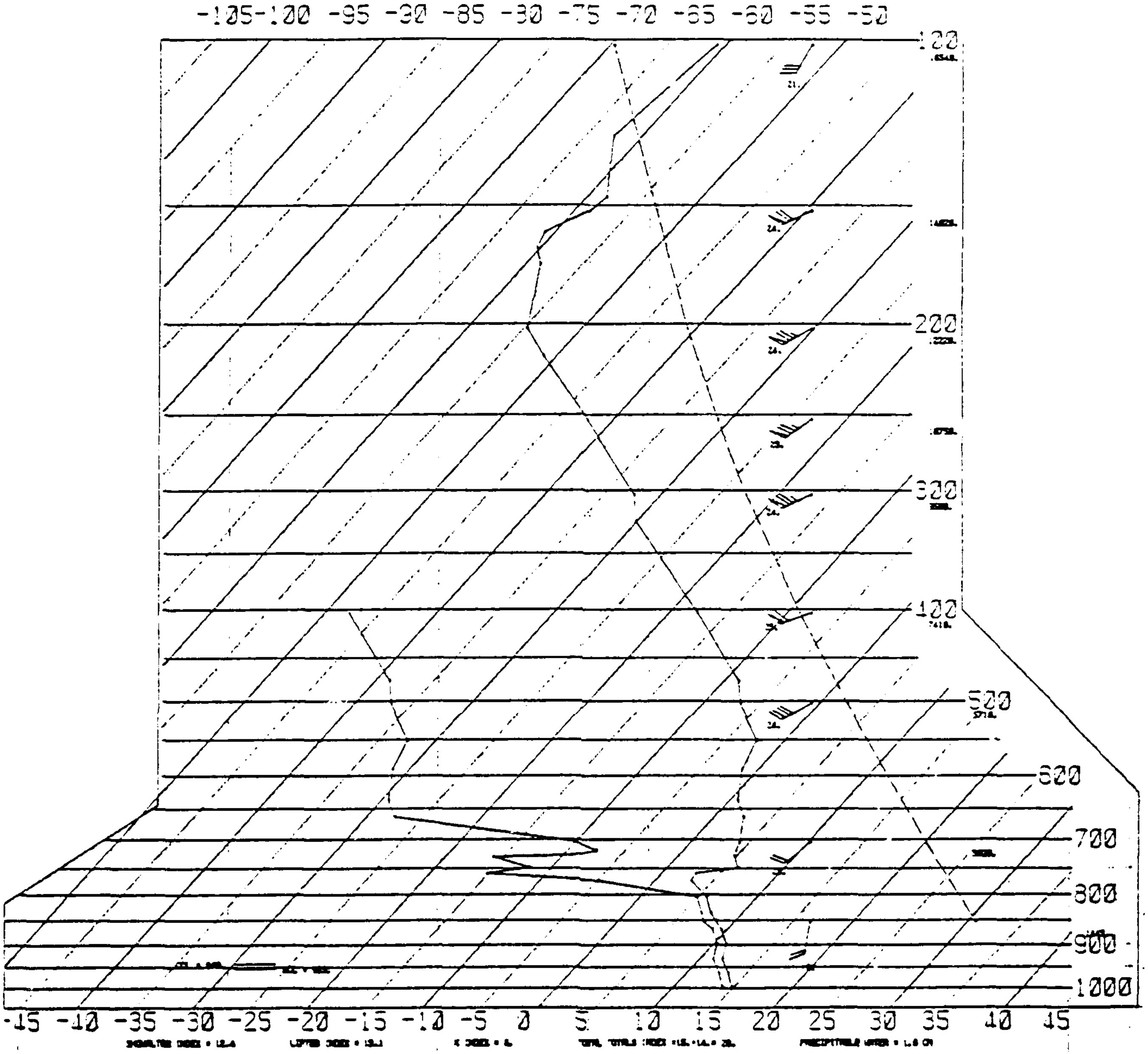



Fig. 5 Vandenberg AFB sounding for 1200 GMT 28 June 1991.

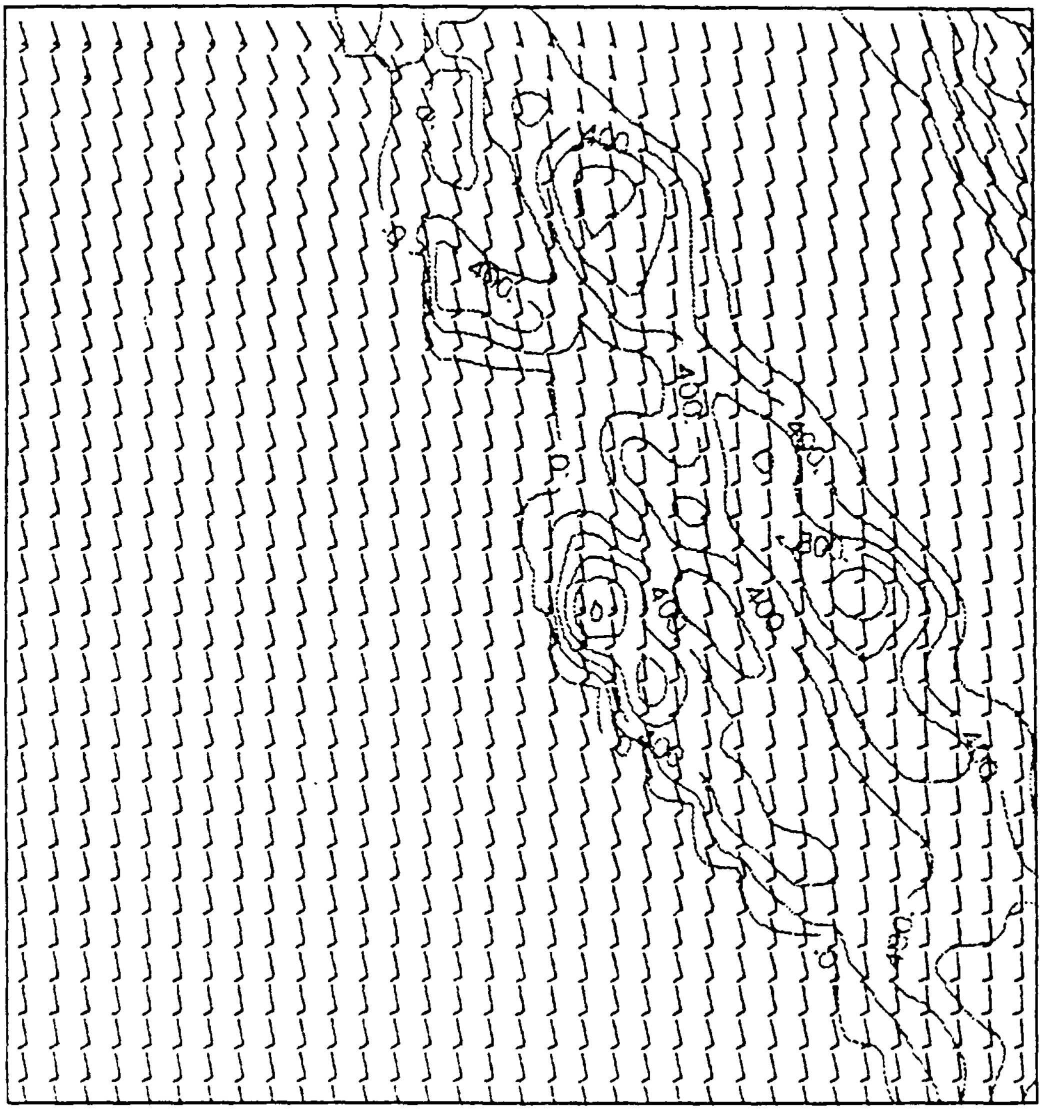


Fig. 6 Lavoie model simulation of wind field for 28 June case. Terrain height is in meters.

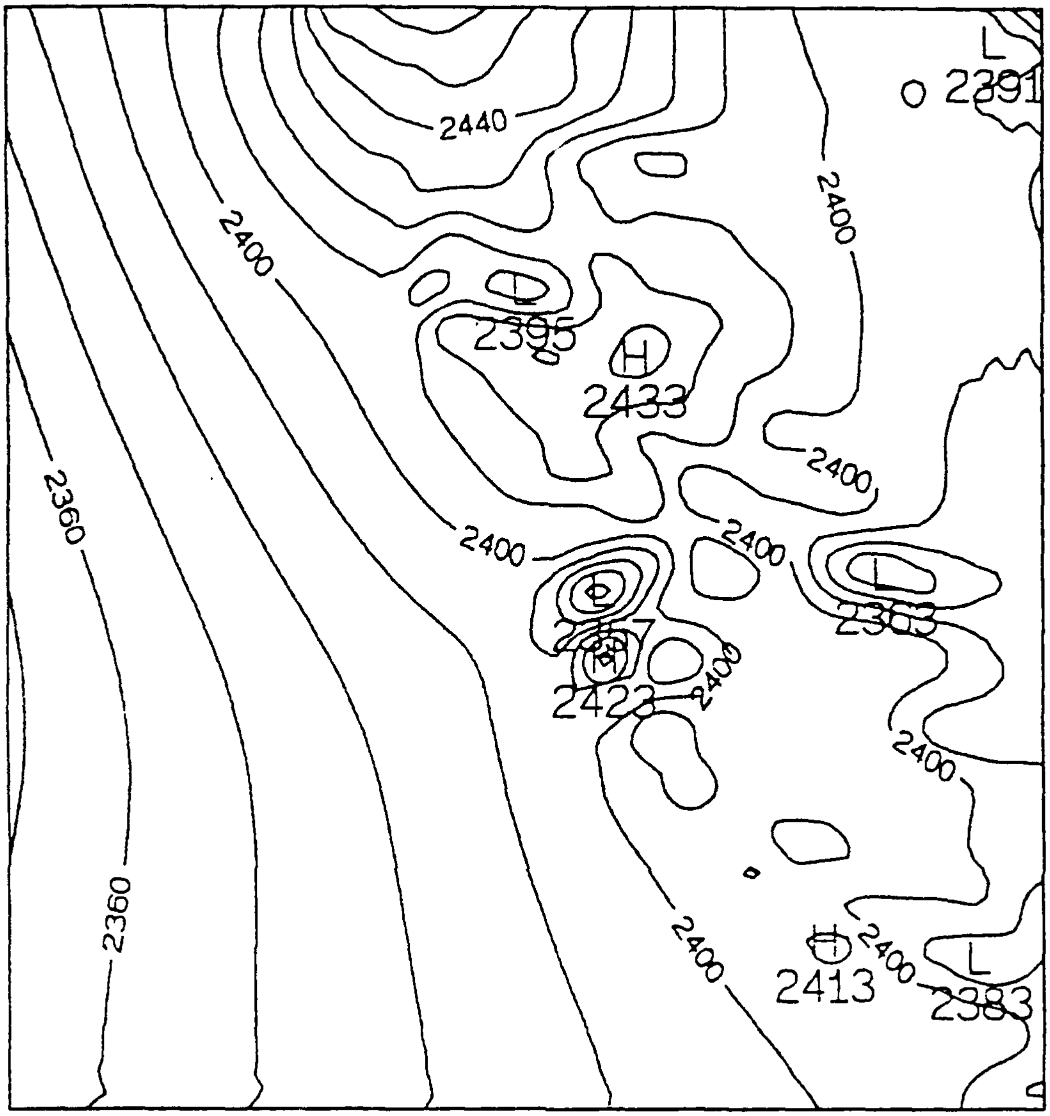



Fig. 7 Lavoie model simulation of mixed layer height field (meters) for 28 June case.

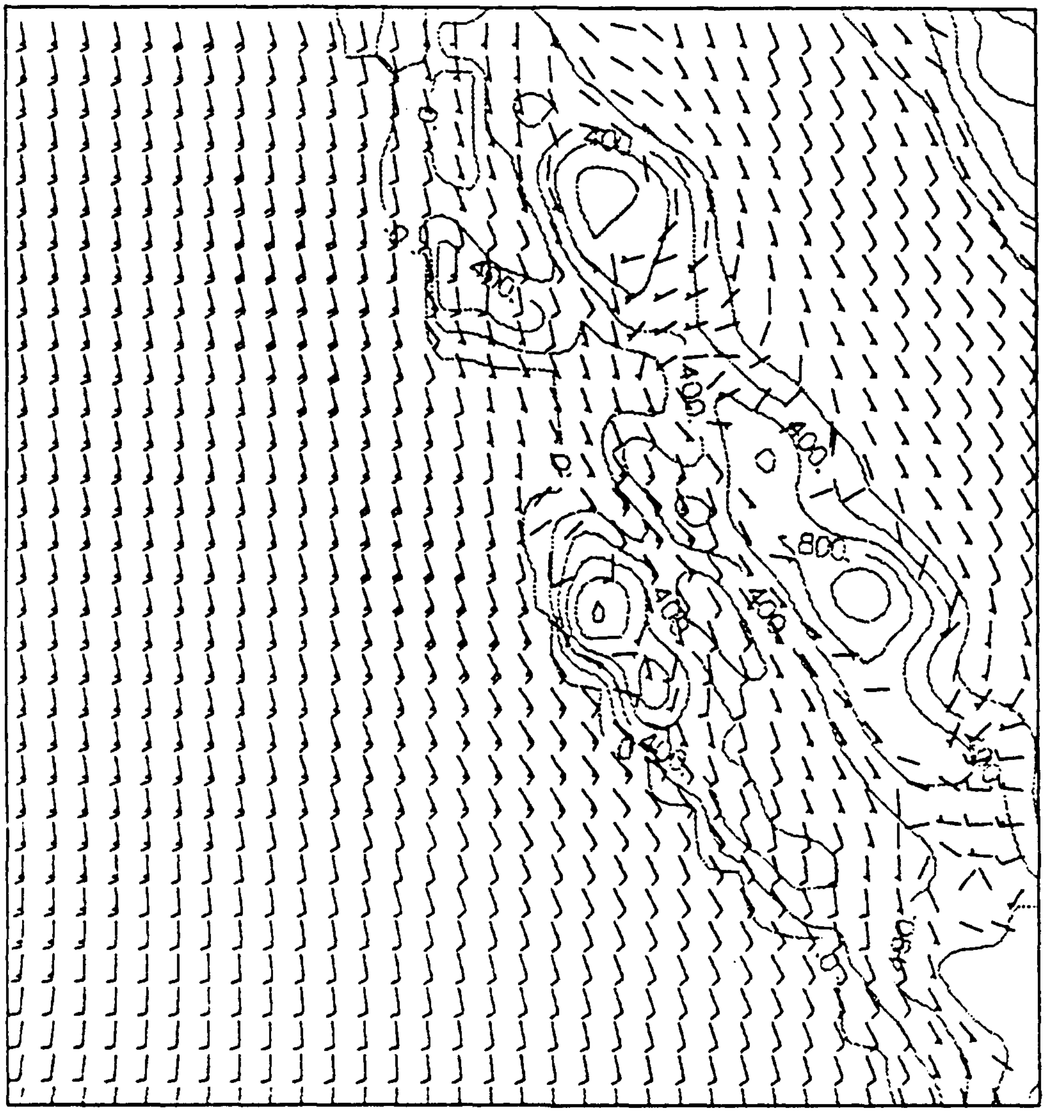



Fig. 8 Lavoie model simulation of wind field for 28 June case with an intialized boundary layer depth of 300 m. Terrain height is in meters.

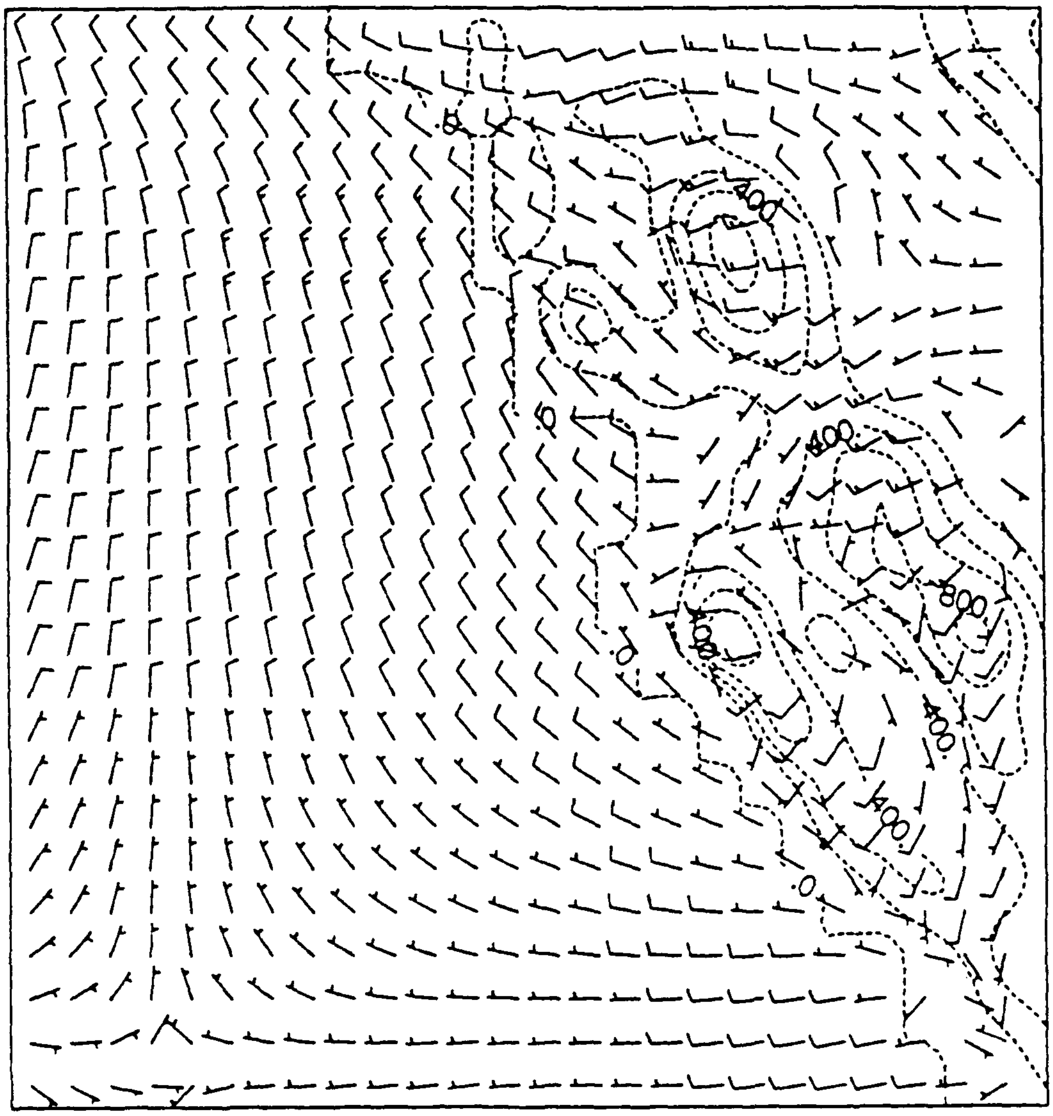


Fig. 9    Mass-Dempsey model simulation of wind field for 28 June case. The run includes diabatic heating. Terrain height is in meters.

gradients of temperature and geopotential height are extracted from a 1 degree latitude by 1 degree longitude region between the trough and the California coast. This region is dominated by the southerly flow ahead of the trough. Figure 10 shows the results of the model run with a constant gradient. The diagnosed winds are southerly with wind speeds generally lower than those observed. The unheated integration (Fig. 10a) demonstrates offshore flow in the Monterey Bay while the heated integration (Fig. 10b) more accurately represents the observed onshore flow.

## 3.2 July 24: Strong Northwest Wind, High Pressure Offshore

On July 24, 1991, a strong surface high pressure cell was located off the California coast. Fog and stratus were present in the early morning, giving way to clear skies and high winds in the afternoon (Fig. 11). Wind observations for approximately 2100 GMT (1400 PDT) show 15-20 knot northwest winds along the coast, evidence of a coastal eddy in northern Monterey Bay, and northwesterly winds throughout the Salinas Valley (Fig. 12).

The Oakland sounding for the 1200 GMT (Fig. 13) displays the "classic" summer profile for the California coast with a shallow, moist marine layer capped by dry, sinking air. The depth of the mixed layer is approximately 629 m (943 mb) with a strong capping inversion ($\Delta\Theta = 17.8°C$).

### 3.2.1 Lavoie Model

For this simulation, the Lavoie model failed to converge. Figure 14 shows the wind field after 30 hours of integration. Comparison with the observed winds (Fig. 12) shows how poor the model simulation is. The model develops a fictitious trough off the coast which results in southwesterly winds over much of the coastal region. Observations are predominately northwesterly. The predicted southerly winds in the Salinas Valley are contradicted by the observations as well.

The model accelerates the winds into the San Joaquin Valley through the San Francisco Bay Area, Pacheco Pass, and east of Paso Robles. While observations for this date do not show this, this pattern is known to commonly occur (Fig. 15).

The predicted heights of the mixed layer (Fig. 16) are higher than the initial value of 629 meters, but the increasing heights appear realistic. The height maxima over Mt. Carmel and San Benito Mtn. are fictious as they are lower than the mountains peaks in the model (i.e. the mountains are protruding through the boundary layer). The height rises offshore are presumably due to mass convergence from the frictional decrease in winds along the coastline.

### 3.2.2 Mass-Dempsey Model

Fig. 17 shows resulting wind patterns for the run. Strong

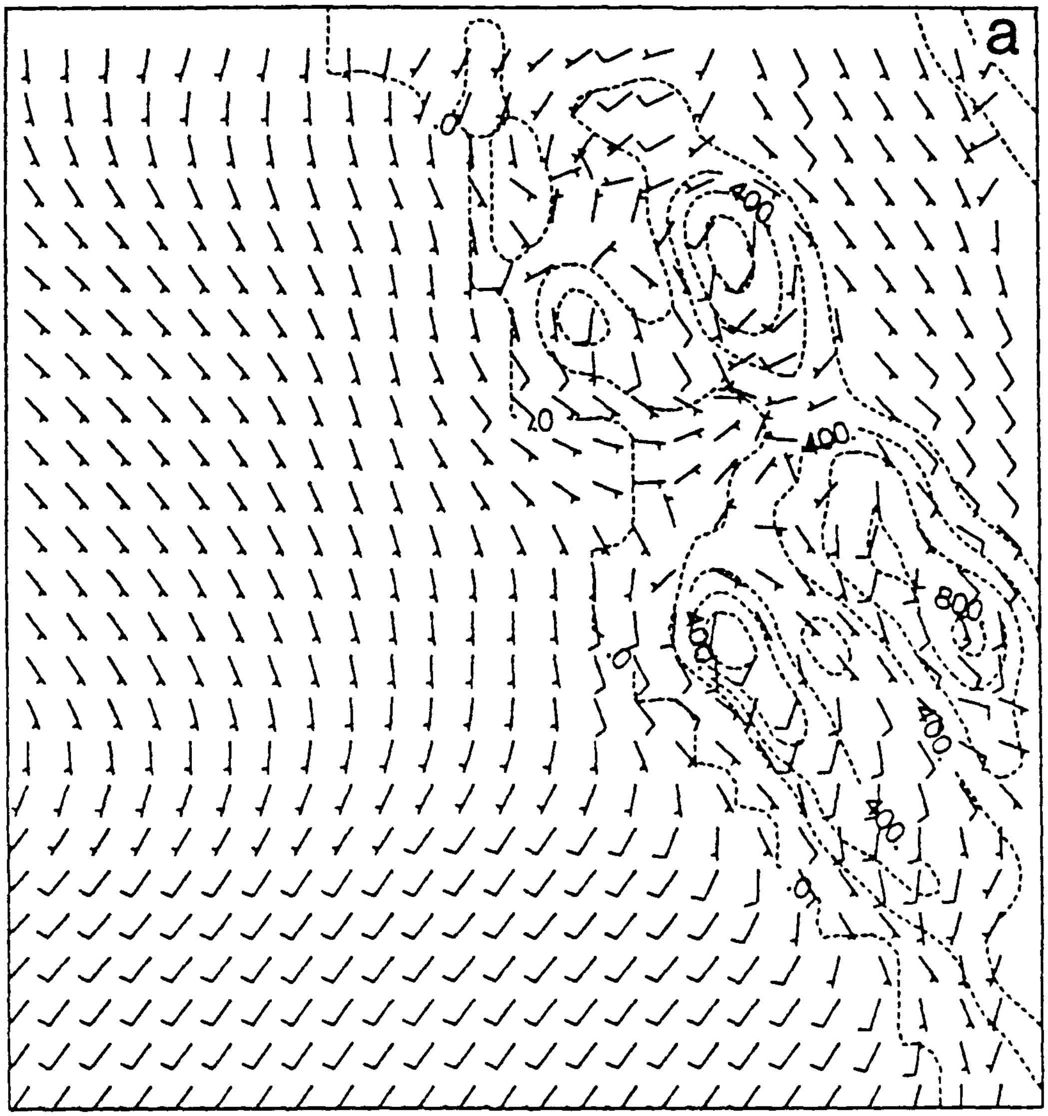



Fig. 10 Mass-Dempsey model simulation of wind field for 28 June case when run with a constant 850 mb height gradient. Figure (a) is results of a run without diabatic heating. Figure (b) shows the results with diabatic heating. Terrain height is in meters.

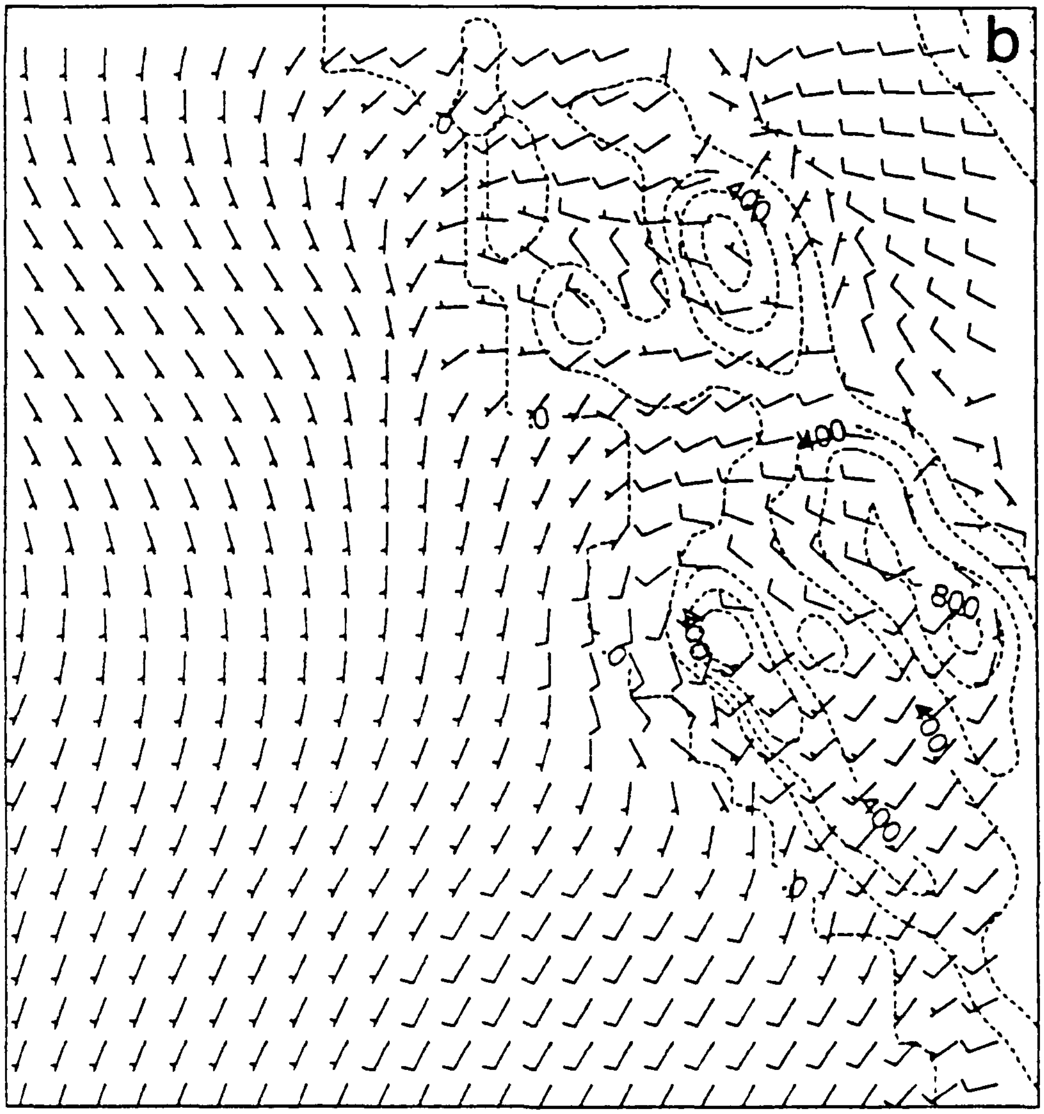



Fig. 10, continued.

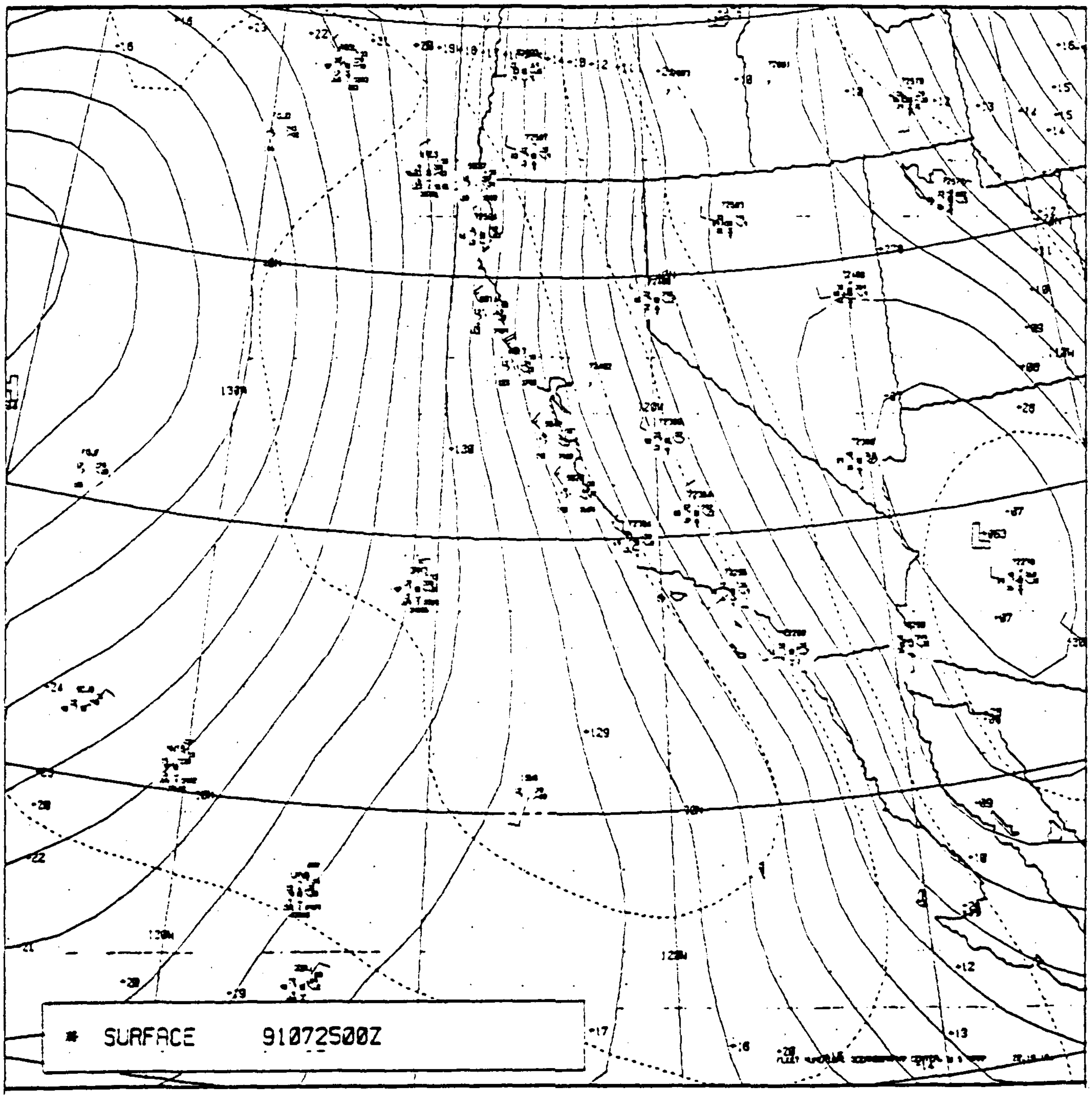



Fig. 11 Surface pressure analysis (contour interval = 1 mb) and observations at 0000 GMT 25 July 1991 (1700 PDT 24 July).

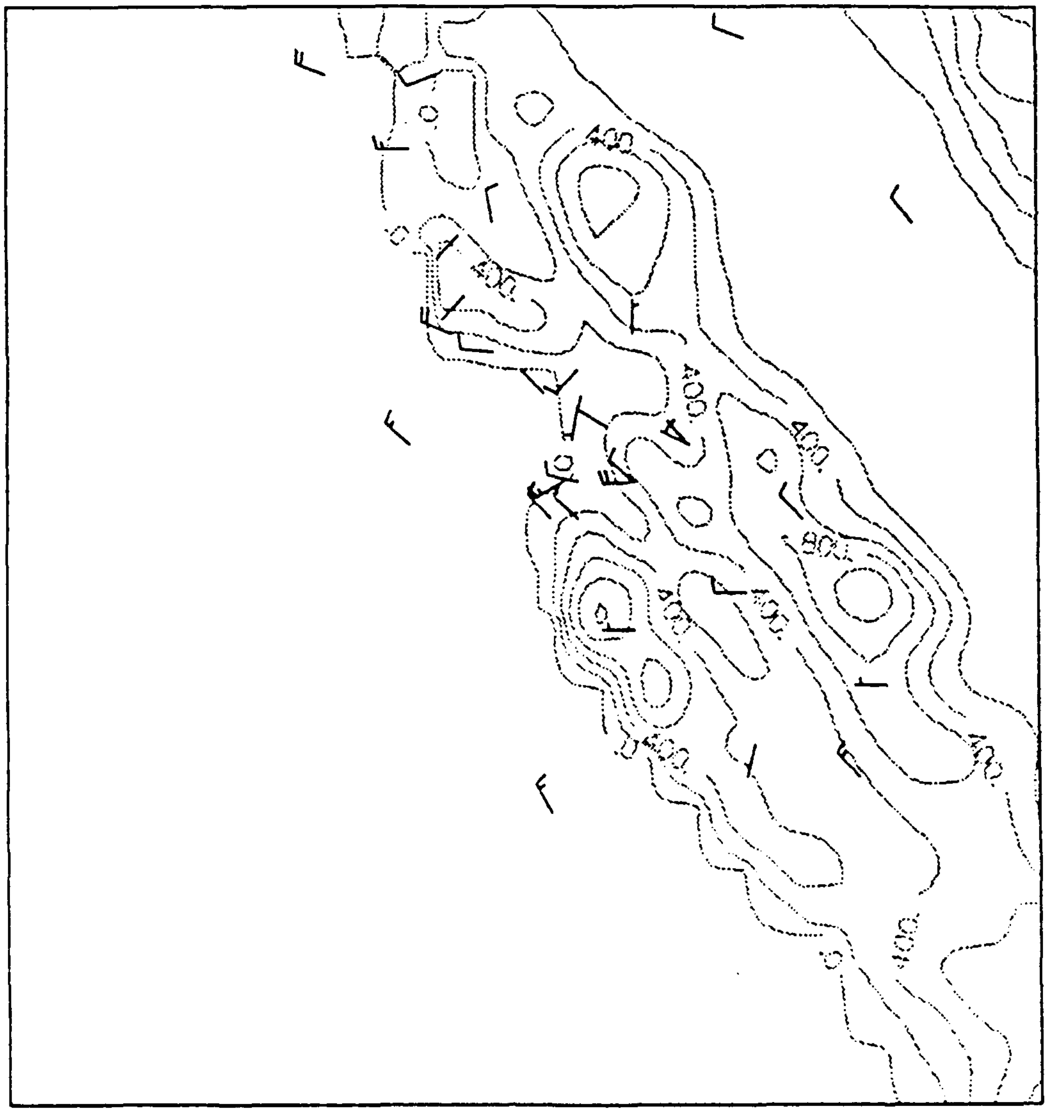



Fig. 12 Surface wind observations at 2100 GMT 24 July 1991 (1400 PDT). Terrain height is in meters.

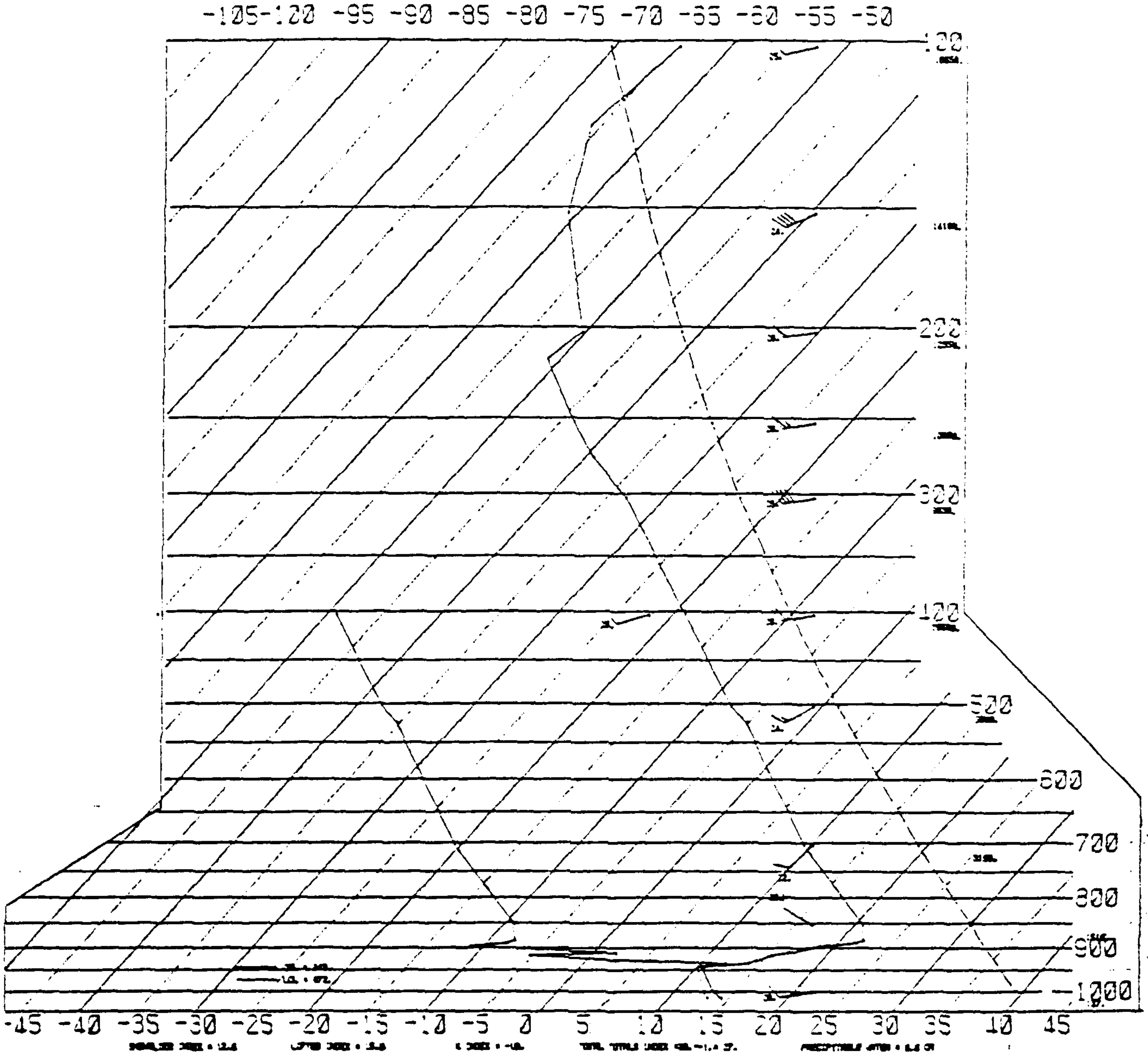



Fig. 13 Oakland sounding for 1200 GMT 24 July 1991.

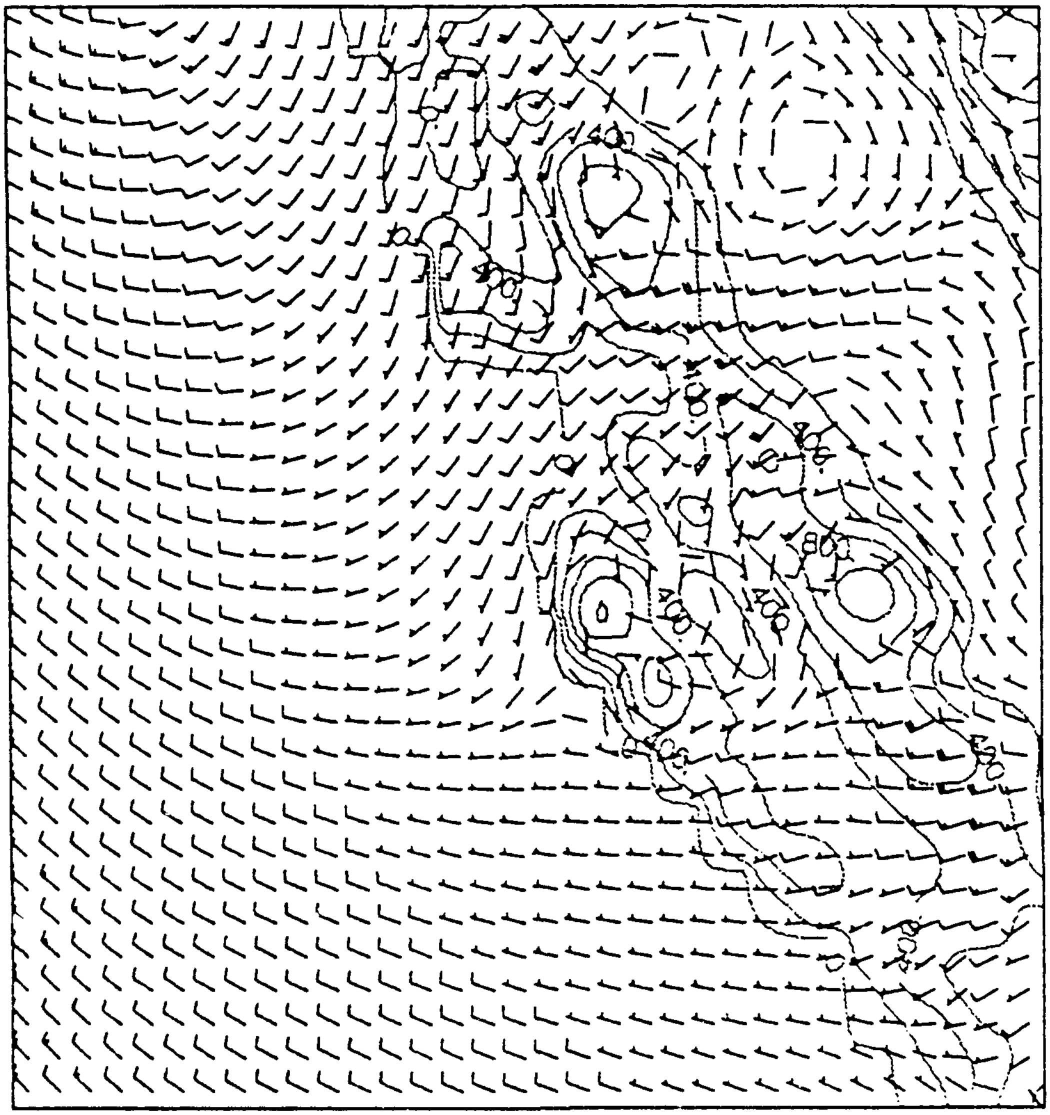


Fig. 14 Lavoie model simulation of wind field for 24 July case after 30 hours of integration. Terrain height is in meters.

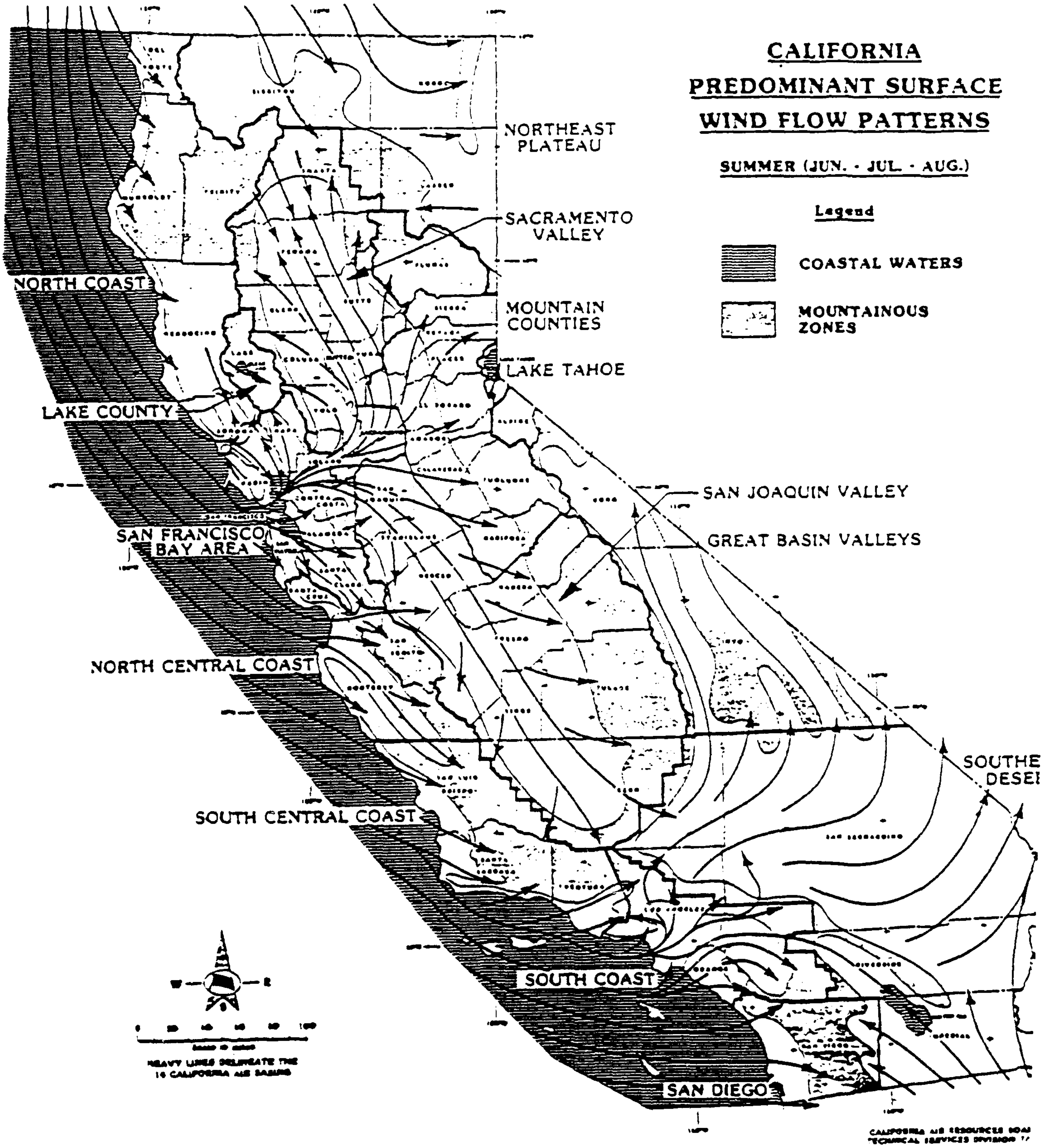



Fig. 15 Climatological summer wind pattern for California (from Hayes et al., 1984).

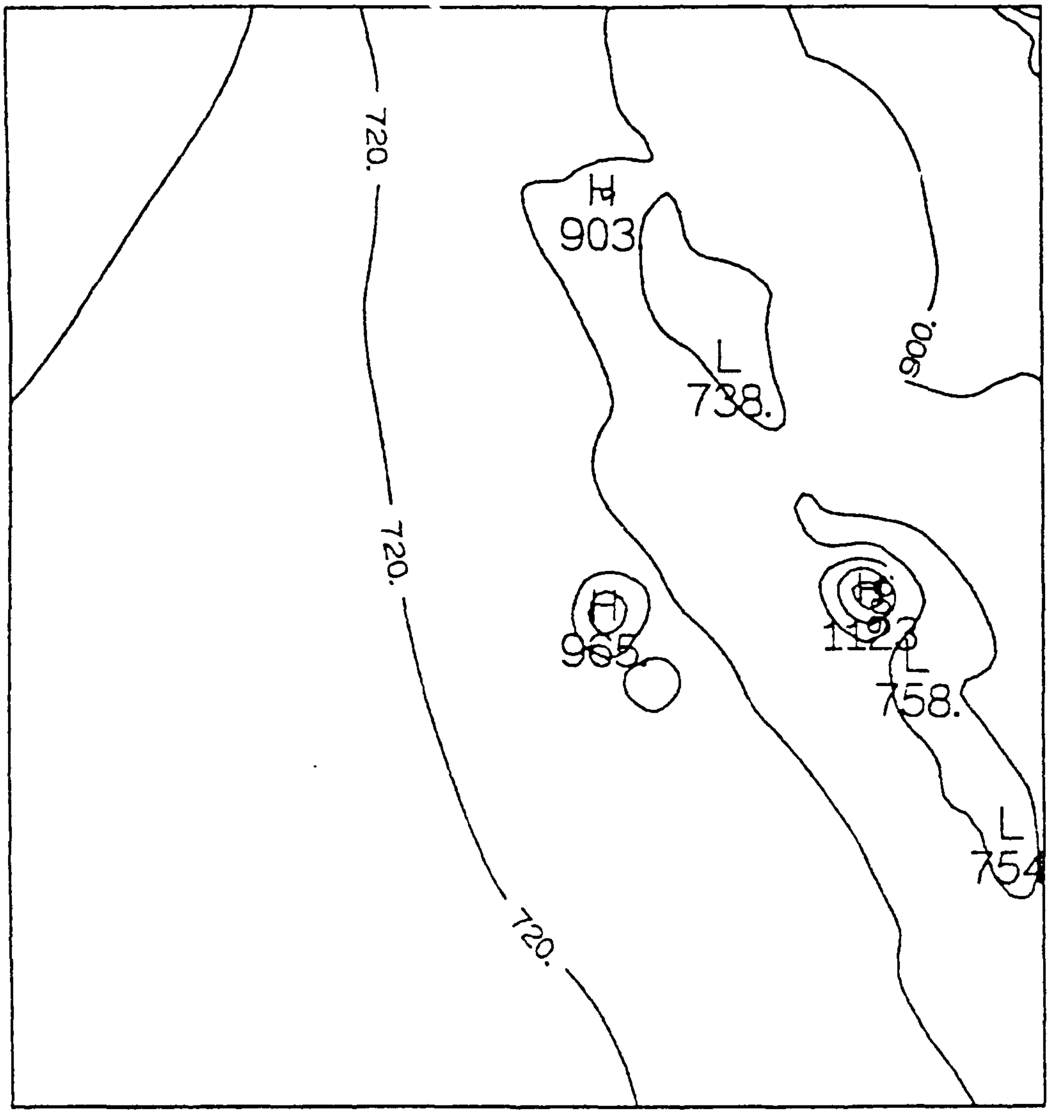



Fig. 16 Lavoie model simulation of mixed layer height field (meters) for the 24 July case.

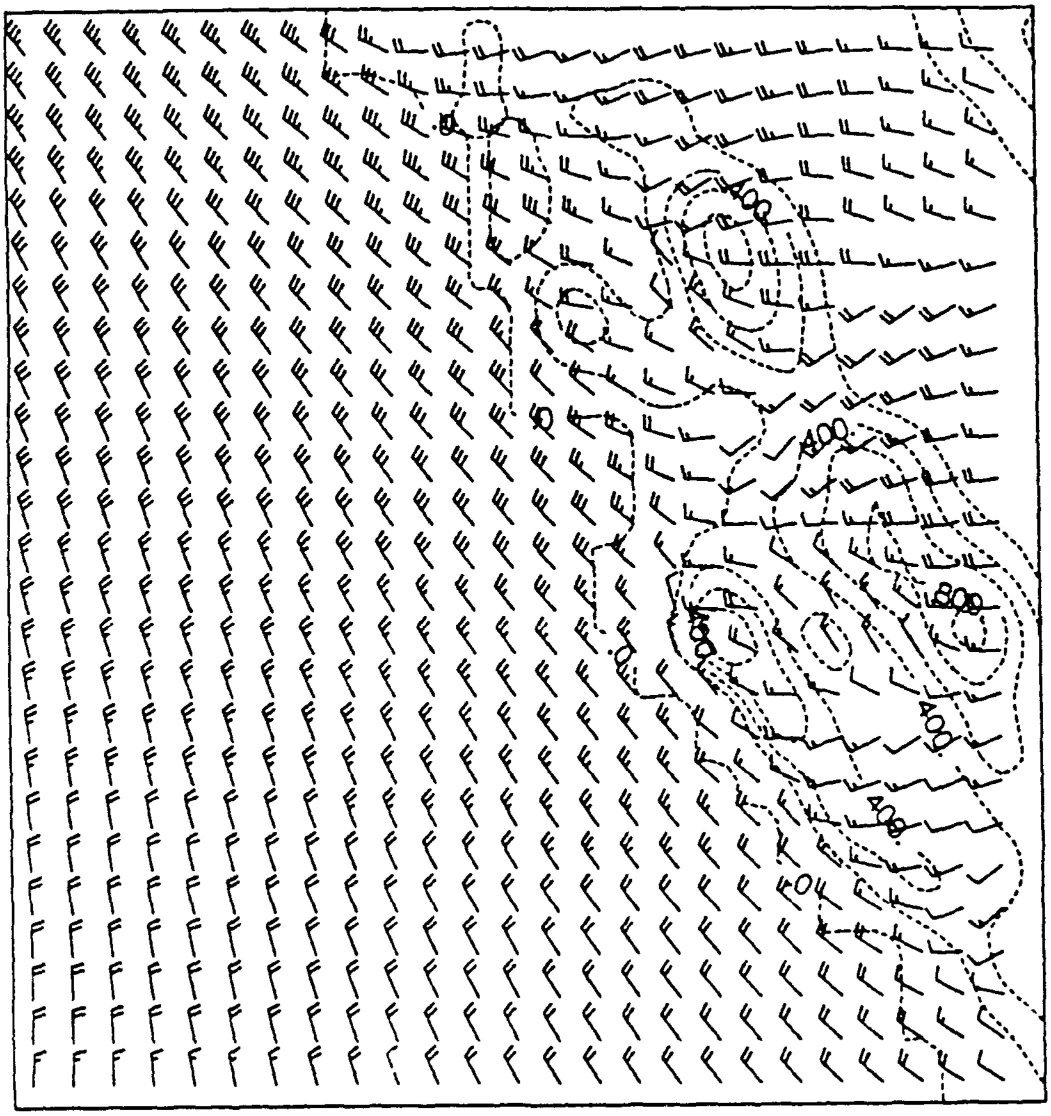



Fig. 17 Mass-Dempsey model simulation of wind field for 24 July case. The run includes diabatic heating. Terrain height is in meters.

northwesterly winds at sea appear to be much stronger than the three buoy observations (Fig. 12).

One possible reason for the overprediction of windspeed at sea is that the drag coefficient over water is a function of windspeed, especially at high windspeeds. Garratt (1977) suggests using a simple linear equation for the drag coefficient at 10 meters based on the windspeed (in m/s) at 10 meters:

$$\text{Drag Coefficient} = .75 + .067 * V \qquad (1)$$

Using this function and the maximum windspeed predicted at sea by the model (35 knots), the results in Figure 18 are obtained. The modeled windspeed at sea has been reduced by an average of 5 knots, but is still higher than observed.

Also, the model predicts westerly winds along the coast south of Big Sur; these winds penetrate the southern Salinas Valley while observations in the region indicate that the mountains block the flow and channel the air through the valley. Climatological data also indicate that the predominant summer flow through the Salinas valley is northwesterly with little indication of westerly flow for the southern Salinas valley (Fig. 15). It is suspected that the terrain data used may not adequately represent the high coastal mountains between the Salinas valley and the coast. Many of the peaks and ridges in these mountains are higher than 1500 meters while the terrain data indicates average heights between 400 and 800 meters.

### 3.3 August 08: Strong Northwest Wind, High Pressure Offshore

On August 08, 1991, a surface high pressure cell was located off the California coast and a trough was approaching the Pacific Northwest. Fog and stratus along the coast cleared by mid-morning and the winds along the coast, which were light in the morning, became quite strong by the afternoon (Fig. 19). Wind observations for approximately 2100 GMT (1400 PDT) show 15-20 knot northwest winds along the coast, evidence of a coastal eddy in northern Monterey Bay, and northwesterly winds throughout the Salinas Valley (Fig. 20).

The Oakland sounding (Fig. 21) is similar to the July 24 case. However, on this day, the marine layer is shallower (240 m) and the capping inversion is not as quite as strong ($\Delta\Theta$ = 15.8°C).

#### 3.3.1 Lavoie Model

Similar to the 24 July case, the Lavoie model develops a ficticious trough offshore (Fig. 22), even to the point of predicting <u>southeasterly</u> winds along the Big Sur coastline. The southerly winds along the coast are totally unrealistic when compared to the observations in figure 20.

The mixed layer depth did rise considerably over the land

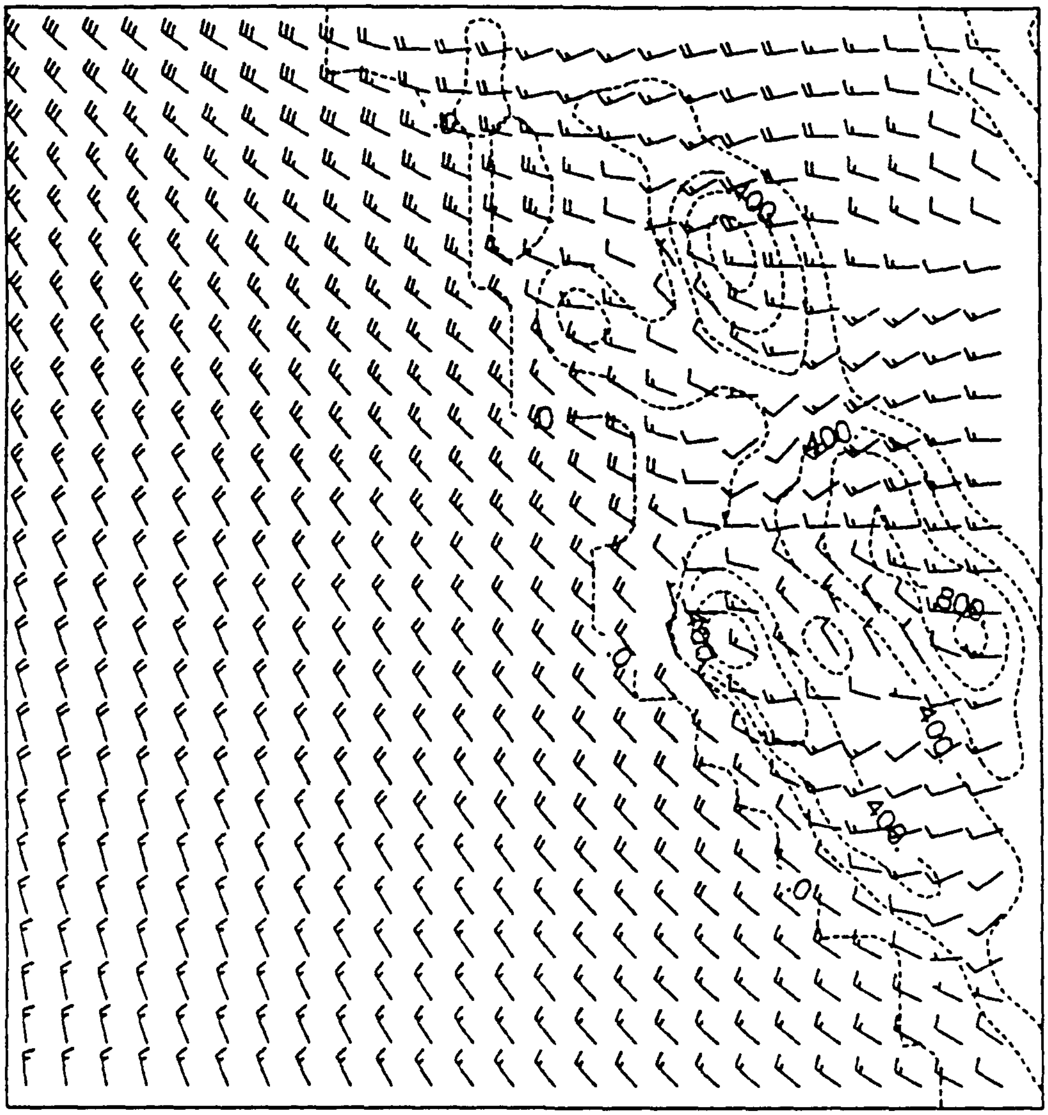



Fig. 18 Mass-Dempsey model simulation of wind field for 24 July case with corrected drag coeffiecient (see text). The run includes diabatic heating. Terrain height is in meters.

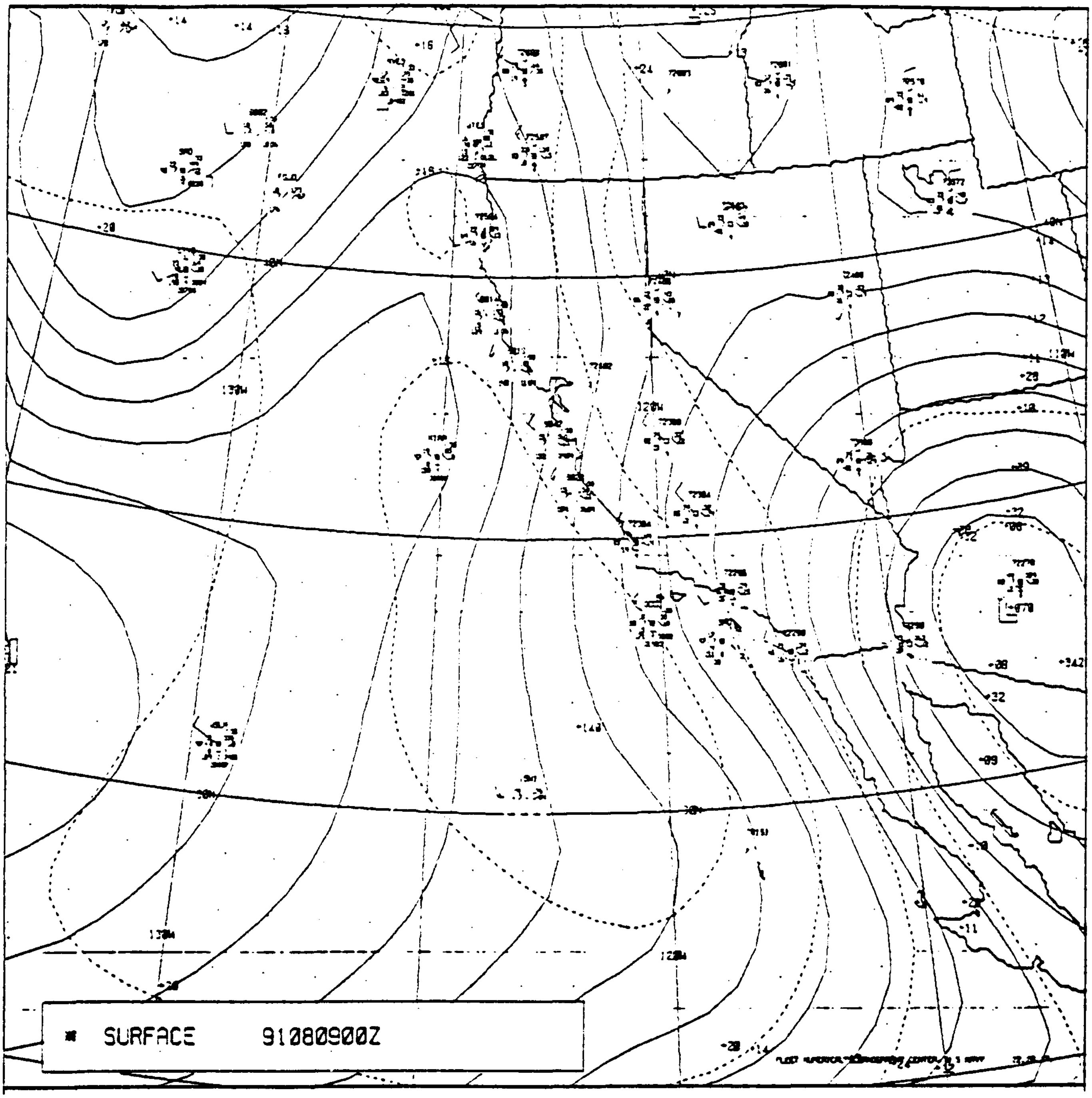



Fig. 19 Surface pressure analysis (contour interval = 1 mb) and observations at 0000 GMT 09 August 1991 (1700 PDT 08 August).

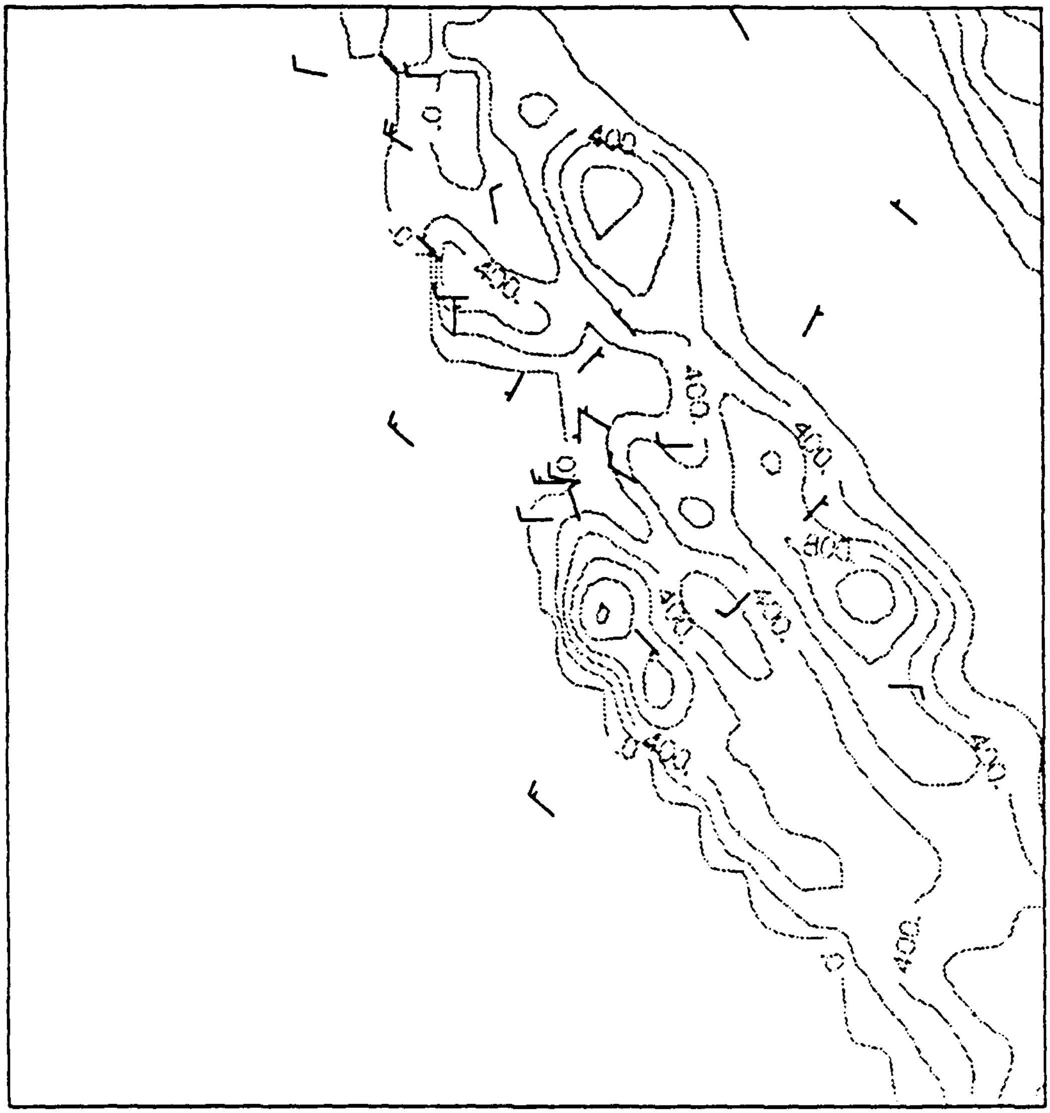



Fig. 20 Surface wind observations at 2100 GMT 08 August 1991 (1400 PDT). Terrain height is in meters.

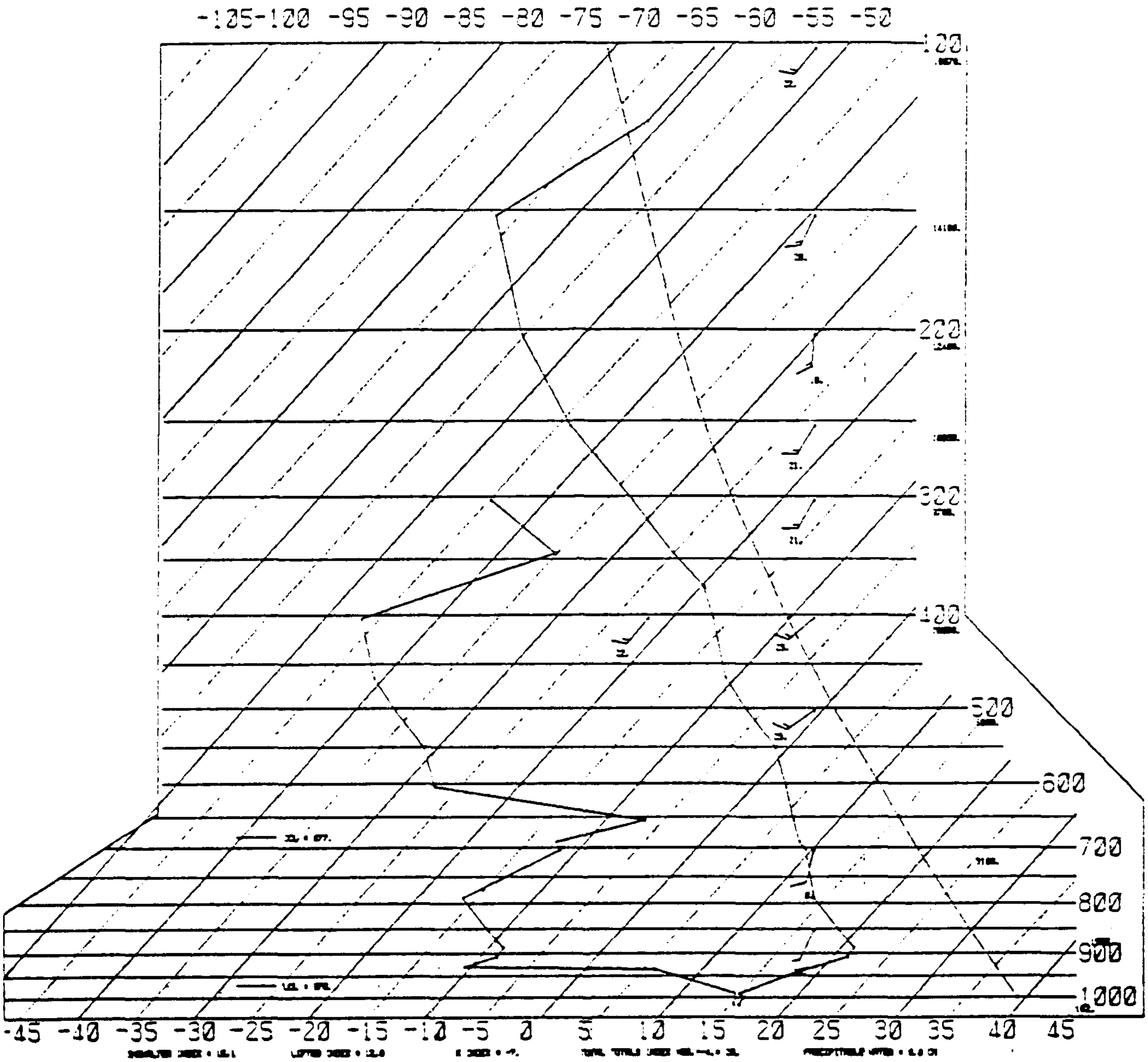



Fig. 21 Oakland sounding for 1200 GMT 08 August 1991.

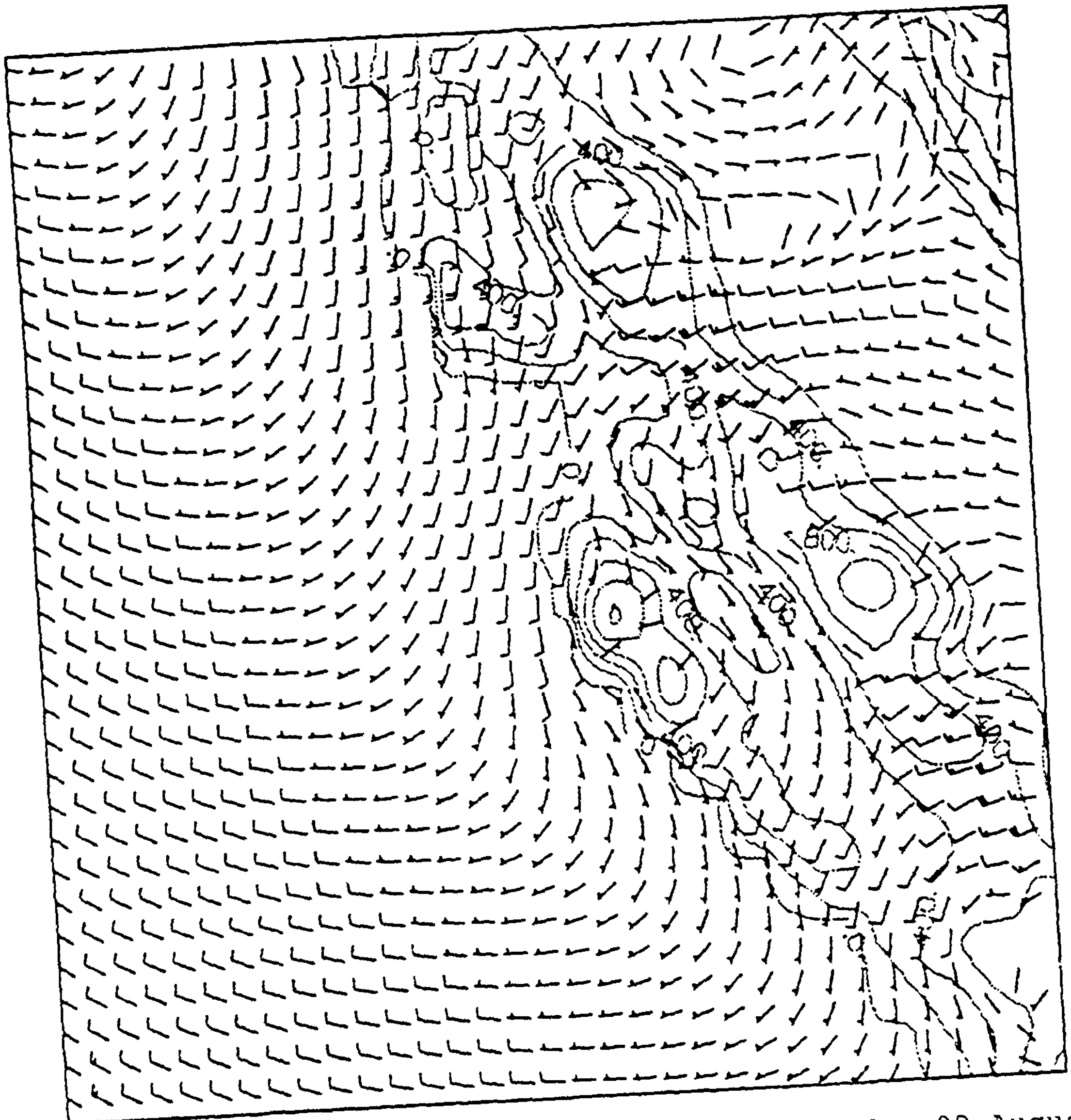


Fig. 22 Lavoie model simulation of wind field for 08 August case after 30 hours integration. Terrain height is in meters.

(not shown) but the major mountain peaks still protrude through the top of the mixed layer. Apparently the strength of the capping inversion correctly acts as a "brake" on upward motions in the Lavoie model.

### 3.3.2 Mass-Dempsey Model

Fig. 23 shows resulting wind patterns for the run. Northwesterly winds at sea appear to be slightly stronger than the buoy observations (Fig. 20). As with July 24, the model predicts westerly winds (along the coast south of Big Sur) which penetrate the southern Salinas Valley while observations in the region indicate that the mountains block the flow and channel the air through the valley.

Using equation (1) to modify the drag coefficient over water produces a slight reduction in the windspeed over water, but results are similar to those shown in Fig. 23 because the modified drag coefficient is not much larger than the original (.0016 vs .0014).

## 4. Conclusions

An evaluation of three mesoscale models has been performed to discern whether any could be of use in TESS.

Initially, a global terrain database was added to the models so that they can be applied anywhere in the world with little effort. Also, a graphical user interface was added to each model so that model operation is a simple task.

Inspection of the data required to initialize the models shows that the Mass-Dempsey model requires a grid of heights and temperatures, whereas the Eddington and Lavoie models require a single unperturbed wind. There is also some skill required in determining the gridded data for the Mass-Dempsey model, particularly if a synoptic feature (e.g., a trough) is within the model domain. If possible, future work on this model should include automating this process.

In running the models to these cases, it was found that the current version of the Eddington model requires five times as much computer time as the Mass-Dempsey model. The computer time required to run the Lavoie model is about half that of the Mass-Dempsey model. The Eddington model must be streamlined somewhat before it can be considered a viable candidate for TESS.

In applying the three models to Monterey Bay Area, it was found that the Mass-Dempsey models performed adequately for the cases studied while the Lavoie model did not. The Eddington model could not be adequately debugged for this study.

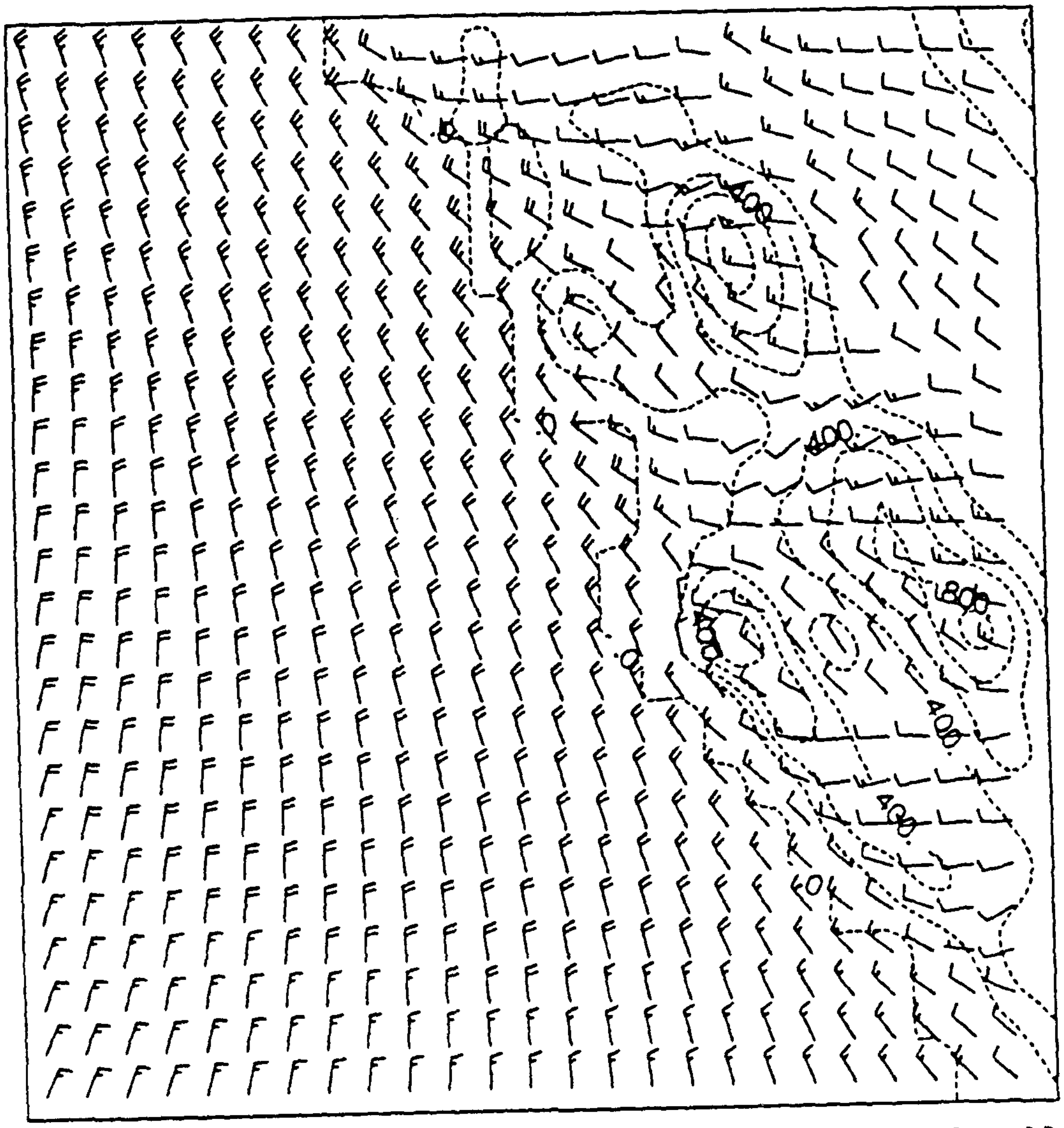



Fig. 23 Mass-Dempsey model simulation of wind field for 08 August case. The run includes diabatic heating. Terrain height is in meters.

## 4.1 Lavoie Model Summary

While the Lavoie model was the fastest model of the three, it appeared inadaquate in that it developed erroneous troughs off the California coast. Test runs on the Washington coast produced similar troughs (not shown). It could not be determined whether this was a result of the model formulation or a coding error.

The Lavoie model did appear to correctly handle the complex topography, producing gap winds and deflected flow around high peaks. The predicted height of the mixed layer showed relative height minima (maxima) downwind (upwind) of the mountain peaks due to sinking (rising) motion.

## 4.2 Mass-Dempsey Model Summary

One problem with the Mass-Dempsey model is that it predicted winds at sea that were too strong. The authors' attempt to adjust the drag coefficient at sea to account for increased roughness resulted in only a slight improvement in the forecasted wind at sea. Another problem is that the Mass-Dempsey model allowed westerly winds from the ocean to penetrate the southern Salinas valley. It is speculated that the effect of the mountains and ridges between the ocean and the southern Salinas valley are not well represented in the model. It may be necessary to scan the database for nearby ridges and peaks rather than reading only the value at the grid point to get realistic flow in areas like the southern Salinas valley.

In summary, the Eddington model and Mass-Dempsey model both performed adequately in the case studies whereas the Lavoie model did not. The main weakness with the Eddington model is that it requires too much computer time to run operationally. The main drawback of the Mass-Dempsey model is that it currently requires some forethought in determining the geopotential heights and temperatures for model initialization. With some effort either the Eddington model or the Mass-Dempsey model could be developed for TESS.

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## Appendix I

## The Lavoie Model

Specifics on operation and modification of the model as implemented on NEONS are described within. Prior to using the model, it is required that users obtain permission and account information from the NEONS system administrator at NOARL.

### 1. Program Operation

The files required to run the Lavioe model are in the directory **/users_xenon/sampson/lavoie/data.** The following is a list of the files in the above mentioned directory.

| Filename | Description |
|---|---|
| 24jul.cc | Script file to run 24jul case, which contains NAMELIST paramters. See main program source code for a description of the NAMELIST parameters. |
| 24jul.obs | Surface wind observations file which may be optionally plotted at the end of the model simulation. |
| land | Land-Sea table subset for repeated runs (see LSETTL variable in NAMELIST) |
| topo | Land-Sea table subset for repeated runs (see LSETTL variable in NAMELIST) |
| output | Output data from model run. |

To run the model:

1) Logon NEON or XENON computer using Reflection 1/7
2) Set terminal type to **hp2627** during logon
3) **cd /users_xenon/sampson/lavoie/data**
4) type **24jul.cc** to run 24 July case
5) Answer questions during execution
6) Laser printed hardcopy is obtained in Bldg 4 (NOARL)

## 2. Program Modification

The source code for the Lavoie model is written in FORTRAN and is in the directory **/users_xenon/sampson/lavoie/src.** Note that these files are stored as SCCS files. See SCCS documentation for more information on how to use these files. The following is a list of files which are relevent for program modification:

| Filename | Description |
|---|---|
| cnvtst.f | tests for convergence to solution. |
| fcstm.f | forecast h,t, and q. |
| fcstw.f | forecast u,v, and w. |
| flds01.f | intializes arrays for a diagnostic test case. |
| flds02.f | intializes arrays for a diagnostic test case. |
| flds03.f | intializes arrays for a diagnostic test case. |
| gmenu.f | shows graphics menu, plots graphics. |
| init.f | initializes arrays for a simulation case. |
| lavoie.f | main program. |
| qprntn.f | quick print arrays. |
| setgks.f | set intial gks parameters for graphics. |
| topo.f | reads NEONS topo and land-sea data base |

To modify program:

1) **cd /users_xenon/sampson/lavoie/src**
2) Make changes to source code or makefile
3) Execute **make**

## Appendix II

## The Eddington Model

Specifics on operation and modification of the model as implemented on NEONS are described within. Prior to using the model, it is required that users obtain permission and account information from the NEONS system administrator at NOARL.

### 1. Program Operation

The files required to run the Eddington model are in the directory **/users_xenon/sampson/tessps/data.** The following is a list of the files in the above mentioned directory.

| Filename | Description |
|---|---|
| 24jul.cc | Script file to run 24jul case, which contains NAMELIST paramters. See main program source code for a description of the NAMELIST parameters. |
| land | Land-Sea table subset for repeated runs (see LSETTL variable in NAMELIST) |
| topo | Land-Sea table subset for repeated runs (see LSETTL variable in NAMELIST) |
| output | Output data from model run. |

To run the model:

1) Logon NEON or XENON computer using Reflection 1/7
2) Set terminal type to **hp2627** during logon
3) **cd /users_xenon/sampson/tessps/data**
4) type **24jul.cc** to run 24 July case
5) Answer questions during execution
6) Laser printed hardcopy is obtained in Bldg 4 (NOARL)

## 2. Program Modification

The source code for the Lavoie model is written in FORTRAN and is in the directory **/users_xenon/sampson/tessps/src.** Note that these files are stored as SCCS files. See SCCS documentation for more information on how to use these files. The following is a list of files which are relevent for program modification:

| Filename | Description |
|---|---|
| cnvtst.f | tests for convergence to solution. |
| fcsth.f | forecast h. |
| fcstm.f | forecast t and q. |
| fcstw.f | forecast u,v, and w. |
| flds01.f | intializes arrays for a diagnostic test case. |
| flds02.f | intializes arrays for a diagnostic test case. |
| flds03.f | intializes arrays for a diagnostic test case. |
| gmenu.f | shows graphics menu, plots graphics. |
| init.f | initializes arrays for a simulation case. |
| setup.f | setup temporary arrays. |
| shift.f | shift t-1, t, and t+1 arrays for next time step. |
| tessps.f | main program. |
| timef.f | time filter. |
| qprntn.f | quick print arrays. |
| setgks.f | set intial gks parameters for graphics. |
| topo.f | reads NEONS topo and land-sea data base |
| wctoa.f | convert u and v from "C" grid to "A" grid for output |

To modify program:

1) **cd /users_xenon/sampson/tessps/src**
2) Make changes to source code or makefile
3) Execute **make**

## Appendix III

## The Mass-Dempsey Model

Specifics on operation and modification of the model as implemented on NEONS are described within. Prior to using the model, it is required that users obtain permission and account information from the NEONS system administrator at NOARL.

### 1. Program Operation

The files required to run the Mass-Dempsey model are in the directory **/users_xenon/sampson/mass/bin.** The following is a list of the files in the above mentioned directory.

| <u>Filename</u> | <u>Description</u> |
|---|---|
| INPUT.DAT | Model parameters used for input. |

```
Line    1: Time, Date, Year
     Line    2: Timestep (Sec.), Unheated Steps,
               : Steps Between Convergence/Output, Conv. Crit.
     Line    3: Ref. Lapse Rate (C/M), Ref. Pressure (mb)
     Line    4: Depth Of Layer Of Topographical Influence (M)
     Line    5: Southern Lat., Northern Lat., Eastern Long.
     Line    6: No. Grid Points (Lat.), No. Grid Points (Lon.)
     Line    7: Drag Over Land , Drag Over Water, PBL Depth Factor
     Line    8: Hours Heating, Length Of Day Or Night (Hours)
     Line    9: Temperature Diff., Momentum Diff.
     Line   10: Number Of Observations At Ref. Pressure
     Line 11-N: Observations At Ref. Pressure
               : Temperature (K), Geop. Height (M), Lat., Lon.
```

| | |
|---|---|
| mass | Executable code for model. |
| PARAMS.OUT | Debugging output listing parameter values. |
| runmass | Batch file for model execution, prints graphics. |
| SLPRES.OUT | Output sea level pressure data from model run. |
| WINDS.OUT | Output wind data from model run. |

To run the model:

1) Logon NEON or XENON computer using Reflection 1/7
2) Set terminal type to **hp2627** during logon
3) **cd /users_xenon/sampson/mass/bin**
4) **runmass**
5) Answer questions during execution
6) Laser printed hardcopy is obtained in Bldg 4 (NOARL)

## 2. Program Modification

The source code for the Mass-Dempsey model is written in FORTRAN and is in the directory **/users_xenon/sampson/mass/src**. The following is a list of files which are relevent for program modification:

| Filename | Description |
|---|---|
| cnvtst.f | tests for convergence to solution. |
| dragco.f | computes drag coefficient, f(stability,surface). |
| grafmenu.f | shows graphics menu, plots graphics. |
| intgrt.f | integrates wind and temperature tendency equations. |
| makefile | file to compile and link model code and libraries. |
| mesmodi.f | main program. |
| output.f | writes output to file. |
| outwv.f | writes wind data to file. |
| slpres.f | computes sea level pressure. |
| trrain.f | reads terrain data from NEONS database. |
| tzref.f | interpolates input data to model grid. |
| wind.f | computes initial surface wind components. |

To modify program:

1) **cd /users_xenon/sampson/mass/src**
2) Make changes to source code or makefile
3) Execute **make**

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Three mesoscale models are evaluated for use in the Tactical Environmental Support System (TESS): single level primitive equation models (the Lavoie and Eddington models), and a one-level sigma coordinate model that uses the primitive equations without mass continuity (the Mass-Dempsey model). The Mass-Dempsey model performed adequately when applied to the Monterey Bay region of California while the Lavoie model did not. Coding errors in the Eddington model prevented an accurate evaluation in this study. The current formulation of the Lavoie model requires less computer time and is easier to initialize than the Mass-Dempsey model. Results show that the Mass-Dempsey model performs well while the Lavoie model does not. Future work on the Mass-Dempsey model should include an effort to improve the initialization so that the geopotential height and temperature gradients represent those of the area of interest.

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